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Devoted to Measurement and Control Problems

Vol. 4. No. 9 · Pittsburgh, Pa. · September, 1931

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New Wire Gage
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The Electrolimit Gage
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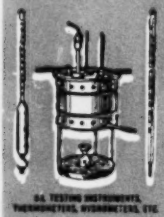

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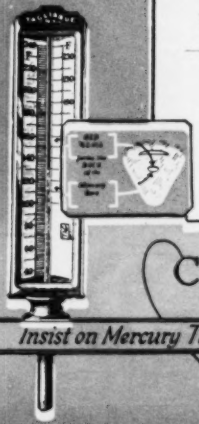

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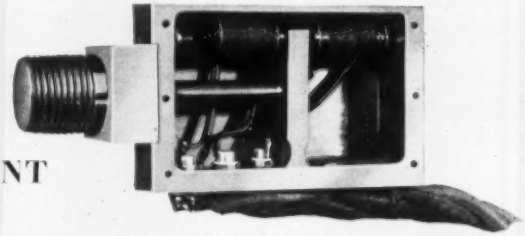

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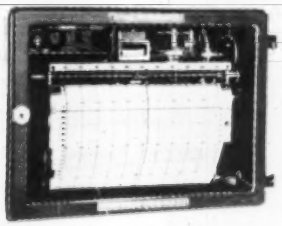

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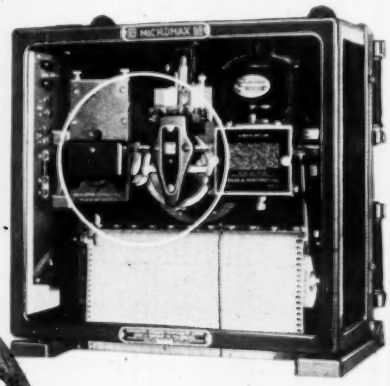

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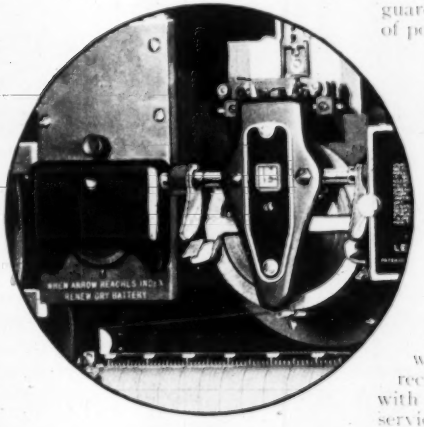

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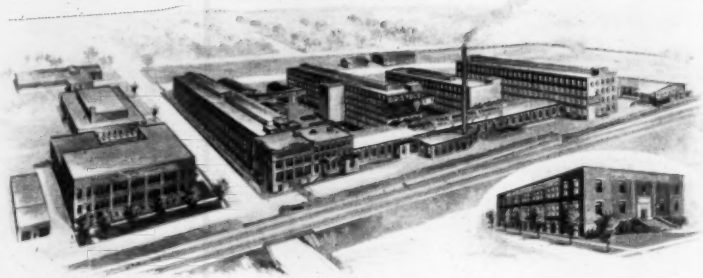

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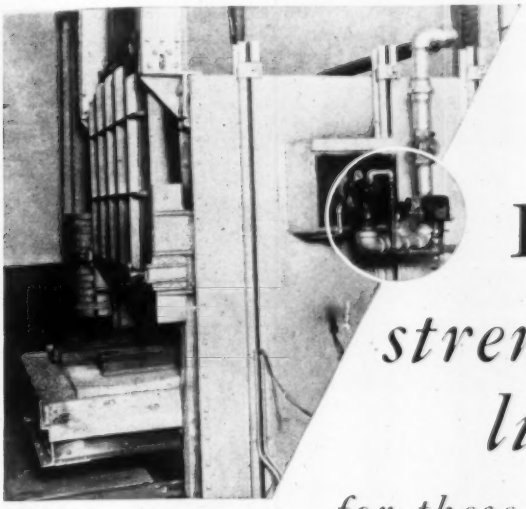

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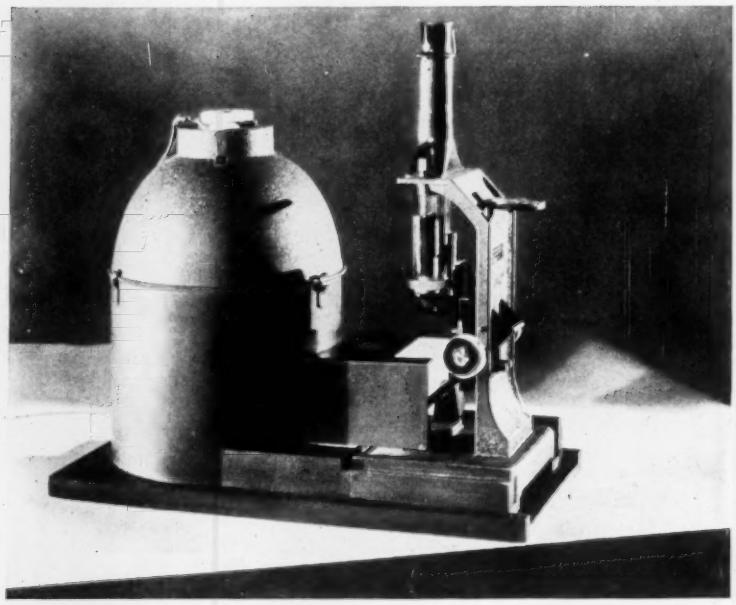

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EDITORIAL COMMENT

"Praise from Sir Hubert"

IT is by no means a rare event for some scientist to express the debt of gratitude which pure research owes to scientific instruments. Sir Oliver Lodge did so on many occasions; before him Lord Kelvin declared that physics is the science of measurement; and the founder of modern empirical philosophy, throughout his *Principia* and *Opticks*, laid stress on the importance of accurate quantitative measurements.

Now and then in these modern times similar tributes are uttered or penned by eminent engineers and industrial leaders in praise of industrial instruments.

There is one industry which constantly uses both scientific and plant production instruments as well as many others which belong to both divisions. That industry is really a group of industries and of research fields including radio, geophysics, sound pictures, traffic control, telephony, electric recording, thereapeutics, etc., etc. In fact we may speak of the electronic industries in the plural number. Their organ is *Electronics* and its editor is O. H. Caldwell.

What Caldwell writes on any subject connected with his industry (rather, industries) is worth reading. What he has to say on instruments if of interest to our readers. Wherefore we take pleasure in reprinting his August editorial:

The Contribution Made By Instruments

THERE is perhaps no field where instruments have played such an important rôle in the advance of an art as in the radio, sound and allied industries.

Instrument manufacturers by their ingenuity, patience and workmanship have produced many standard and special instruments to meet the most exacting requirements of development engineers and the production line. To make even a partial list of such instruments, would run up into the hundreds. Instruments are man's most valuable tools. Perhaps the "ingenuity" of man has not increased since the stone age, but the development of instruments has made possible the crowning of many geniuses in modern times.

The electronic industries owe much to the instrument makers for their assistance in the past, but even more so, each manufacturer in this field owes it to himself to equip his engineers with the latest of instrument models in order that even greater advances in the art may be expected. Instruments are the wherewithal to carry forward into practical development the revolutionary advances made in an infant industry during the past decade.

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The Optical Works of E. Leitz in Wetzlar, Germany have completed their 300,000th Microscope. This instrument was presented at an appropriate gathering to Geheimarat Professor Dr. Ludwig Aschoff of Freiburg in Breisgau, Germany, a scientist and physician of world renown in the pathological and anatomical field of scientific endeavor.

The dedication of this microscope follows a custom of the firm of E. Leitz to present every 50,000th Microscope to an outstanding scientist or institute, thus expressing their appreciation for the cooperation extended by leading authorities to the Leitz Works.

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300,000	Dr. Ludwig Aschoff in Freiburg in Breisgar

The Determination of Low Permeability

*Frank P. Fahy**

THE increasing growth of interest in magnetic properties and their determination has comparatively recently been actively extended with regard to materials of very low or feeble permeability.

The field of measurement of magnetic permeability of sheet, cast and magnet material, as essential elements of construction of electrical apparatus and instruments is at present quite adequately covered. Here the tests are of bodies ranging from very high to high, medium and moderately low permeability and the literature on methods of tests is quite extensive. This is not the case with materials of very low permeability, under which may be classed those ranging from unity (the assumed permeability of empty space) or the "non-magnetic condition" to those having a permeability of 5 or somewhat more.

The need of measurement of very low permeability arises from the use of materials as elements of structure under circumstances where a magnetic characteristic markedly greater than unity is undesirable. An example is found in the use of metals in aircraft in locations where the magnetic property would interfere with the efficient performance of direction indicating means. Again, the employment of material such as non-magnetic cast iron in dynamo-electric machinery where it is essential that this does not act as a flux path of low reluctance. These represent one aspect.

For the other, there is the growing need and use of magnetic measurement as a means for studying both the state and stability of materials of construction which in their optimum state are presumed to be non-magnetic. The leading case is that of some of the later austenitic steels which are, at least in theory, non-magnetic but which through exigencies of manufacture, handling in fabrication, conditions of use or even inherent non-stability are liable to departure from that state. In such cases, the magnetic characteristic serves purely as an index of condition and much attention has been aroused with regard to interpretation in terms of modified strength and ductility, decreased resistance to corrosion and so on.

Granting the requirement of ascertaining the magnetic condition of such materials as fall into the classes cited, some ways and means of making the desired examinations will be considered.

Let us treat first of determination of magnetizability, as distinct from accurate measurement. This permits the use of devices which serve qualitatively rather than quantitatively. One such, in its simplest form, is shown in Fig. 1 wherein A is a permanent magnet of the horse-shoe type on each leg end of which is attached a pole piece extension of highly permeable magnetic material designated as B. Encircling the extensions B are coils C consisting of many turns of fine wire so connected in series that when the free ends of such extensions are bridged by a magnetizable body the electromotive force impulses induced are additive. The indicating instrument D connected in series with the coils C serves to indicate the existence and magnitude of such electromotive forces.

*Magnetic Test Engineer, New York, N. Y.

In the use of the device of Fig. 1, the ends of the pole pieces B are brought into proximity or actual contact with the body to be tested. If such body is magnetic in character, both the total flux and its longitudinal path within the extensions B are modified with a consequent change in linkage, observable through an impulsive throw on the instrument D. Roughly, such impulse is proportional to the susceptibility. It is found in practice that the indications are more consistent and reproducible when the impulse is observed upon *removing* the poles from contact or proximity, rather than upon application. This is because the end condition of actual or quasi contact with the body is the more readily adjusted when the poles are at rest. The other end condition, away from the body, is not a critical one.

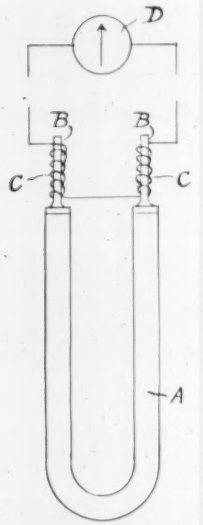

Fig. 1 Device for indicating magnetizability

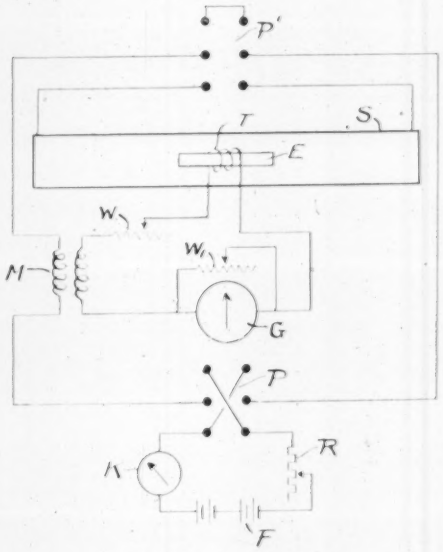

Fig. 2 Standard solenoid test

In principle, the contrivance described is essentially that of the ordinary telephone receiver with the diaphragm removed. However, for best functioning with respect to sensitivity careful design is important and it is desirable to include means in combination with the indicator so as to permit adjustment of the latter with reference to a standard of flux change. An advantage of the method is that it is applicable to fairly large or very small bodies and permits of highly local determinations. It has the advantage of not giving results in standard units, but as a means of obtaining comparative measurements it is extremely useful.

To obtain measurements in standard units there are two methods which may be discussed here, both of which require test specimens of uniform section. In Fig. 2 is illustrated the more or less classical method wherein a specimen under test, E, is shown located at the central interior region of a solenoid, S, the winding terminals of which are connected to one side of a double-pole, double-throw switch P', the other side being cross-connected. The middle points of the switch P' are connected to a source of direct-current electromotive force, F, through a variable rheostat R, ammeter K, reversing switch P and the primary winding of a calibrated mutual inductor

M. Located at the central interior region of the solenoid S is a test winding T of known number of turns, adapted to receive the specimen E and connected as shown through the secondary winding of the inductor M to a galvanometer G. In this test or secondary circuit are resistances W and W_1, respectively arranged to provide series and parallel control of the sensitivity of the galvanometer.

Provided that the permeability of the specimen E is not markedly greater than unity, its self-demagnetizing effect is negligible and the ampere-turns per cm. of length of the solenoid may be taken directly as a measure of magnetizing force. A preliminary step to the test involves the calibration of the galvanometer to permit reading of the flux to be observed in standard units. With no specimen within the solenoid, switch P^1 is closed on its cross-connected side so as to cut out the solenoid winding from the primary circuit and the variable inductor is set to any desired value. Knowing such value, the number of turns in the winding T and the cross-sectional area of the specimen E, a value of current is computed, the reversal of which corresponds to a definite flux-change per unit area of section of the test specimen. Adjustment of the galvanometer to this basis is made by means of the resistance W, so as to permit direct reading from the scale. This calibration being effected, switch P^1 is closed so as to include the solenoid winding in the primary circuit.

The next preliminary step calls for so interconnecting the secondary winding of the inductor M and the test winding T that upon reversal of current in the primary circuit the respective induced electromotive forces will be in opposition. Finally, the inductor value is adjusted by trial so that for reversal of any value of primary current there will be no deflection of the galvanometer. Under these circumstances, subsequent insertion of the specimen E, with reversal of the current, will cause a galvanometer deflection proportional to the intrinsic induction corresponding to the particular magnetizing force applied.

The especial advantage of the variable inductor is that it permits the use of the galvanometer at its highest sensitivity for the measure of the flux individual to the specimen. That is, the winding T must be sensibly larger in section than the specimen to permit of the latter's insertion. Again there may be cases where it is desired to provide for the examination of differently-sized samples, whence it follows that it embraces flux which may often be much greater than the quantity under measurement. The inductor therefore balances out that portion of the flux which would normally obtain in the absence of the test specimen. The indicated flux is then the pertinent quantity, or intrinsic induction, B_i, and to this must be added the value of the magnetizing force, H, acting in order to obtain the induction, B. The induction B divided by the magnetizing force H expresses the permeability.

In the ideal circumstances, the setting of the inductor for any specimen is made once for all. Without further adjustment the variation of the intrinsic induction with magnetizing force may be readily noted for a wide range of values of the latter within the compass limited by heating of the solenoid and the inductor windings.

The method of Fig. 2, as pointed out, presupposes that the specimen E has a permeability approaching unity and that the magnetizing force can be computed directly from ampere-turns. Where the departure from unity is relatively great, however, there is a demagnetizing effect which must be taken into account. This effect acts in two ways: 1. The actual magnetizing force becomes indeterminate from ampere-turns; 2. The setting of the

inductor M must be made anew for each value of magnetizing current.

There are other practical limitations involving inductor design, difficulty in applying high magnetizing forces and heating effects on the test winding. In Fig. 3 there is shown a form of apparatus for low permeability testing

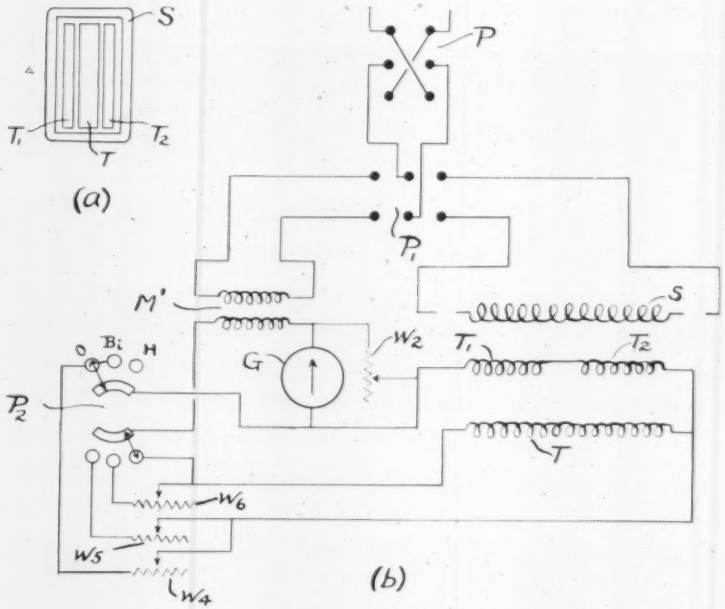

Fig. 3 Modified solenoid test

which overcomes such disabilities by a construction making the magnetizing force measurement and extraneous flux deduction elements an integral part of the secondary system. In this figure (*a*) represents an end elevation of a magnetizing solenoid of rectangular section within which, at its center of length, are three test windings T, T_1 and T_2. T is the winding within which the test specimen is to be inserted while T_1 and T_2, arranged on either side, serve as search coils for direct measurement of the magnetizing force. These latter coils are connected for series addition and are so wound that the combined sum of their area-turns (mean sectional area of winding × number of turns) is very slightly in excess of the area-turns of the winding T.

The electrical connections are shown schematically in Fig. 3 (*b*) wherein S is the magnetizing solenoid connectable through one side of a double-pole, double-throw switch P_1 to a reversing switch P served from a source of electromotive force having an interconnected rheostat and ammeter as shown in Fig. 2. The other side of switch P_1 leads to the primary of a fixed-value inductor M', the secondary of which is in circuit with a galvanometer G and a dial switch P_2 of the double-pole, triple-throw type. The latter is connected so as to permit selective adjustment and observation of the electromotive forces induced as hereafter described. The resistance W_2 provides for parallel resistance control of the galvanometer.

The method of magnetizing force measurement of the apparatus of Fig. 3 rests upon the principle that the air flux per unit section at the central region of the solenoid S provides a direct measure of such force. When the area-turns of either the winding T or the combined windings T_1-T_2 are known, either may serve as a basis of measurement.

In the operation of the apparatus and preliminary to insertion of test material within the coil T, switch P_1 is thrown to the right and adjustment is made by means of a resistance W_4 so that with switch P_2 on the point O the galvanometer deflection is zero when current in the solenoid S is reversed or otherwise modified by the use of the switch P. Under these conditions the *effective* area-turns of the combined windings T_1-T_2 just balances the actual area-turns of the winding T for all values of magnetizing current. The windings T_1 and T_2 thus not only replace the secondary winding of the variable inductor M of the apparatus of Fig. 2 but in addition provide a means whereby the magnetizing force becomes determinate at all times for a wide range of specimen permeability.

When the balance as described is reached, it will be clear that the insertion of a test specimen within the winding T will lead to a galvanometer deflection, upon reversal of the switch P, related to the intrinsic induction. To permit of the measurement of such induction in absolute units, together with the corresponding magnetizing force, requires calibration of the galvanometer G. It is essential to such calibration that the number of turns in the winding T be known; likewise the area-turns value for the winding T_1-T_2. The former should be accurately counted at the time of constructing the coil. The area-turns of T_1-T_2, however, are best determined by means of a standard solenoid measurement. The values are obtained once for all.

Consider first the calibration of magnetizing force, H. When the switch P_2 is on the point H the galvanometer is connected through the secondary of the fixed inductor M' to the winding T_1-T_2 in such manner that the balancing resistance W_4 is withdrawn. Thereupon the switch P_1 is closed so as to allow current to pass through the primary winding of the inductor, the value of the current being adjusted with regard to the constant of the winding T_1-T_2 so that its reversal corresponds to a definite flux change. Adjustment of the galvanometer on the basis of such flux change is made by means of the resistance W_5 so that the magnetizing force may be read directly from the instrument scale in the course of a test.

The calibration of the galvanometer to permit direct reading of the intrinsic induction is made in a similar manner, in which case switch P_2 is on the point B_1. Here, the winding T and the combined windings T_1-T_2, the latter as shunted by W_4, are connected in series opposition through the secondary winding of the inductor M' to the galvanometer, the resistance W_6 serving for the scale adjustment. After calibration is effected, switch P' is thrown over to serve the solenoid for the carrying out of the actual tests.

Important advantages are found in the apparatus of Fig. 3 in that the coil T may be so shaped as to accommodate a wide range of sections. Again, no severe limitations as to length of solenoid are imposed when the magnetizing force is measured through the medium of the search coils described and it becomes possible to employ a quite short solenoid in combination with a yoke for completing the magnetic circuit. Such yoke can itself carry a magnetizing winding and thus assist in the carrying out of tests under forces far beyond the range normally applicable with the apparatus of Fig. 2.

Measurement of Air Flow

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CHAPTER VIII.

MISCELLANEOUS METHODS OF FLOW MEASUREMENT DEPENDING ON PRESSURE OBSERVATIONS.

Measurement of Flow in Small Pipes.—The Pitot-static tube of the standard type is not suitable for traversing a pipe of less than about 6 inches diameter. It will be recalled that when this instrument is used to determine the volume, observations must be made at points whose positions are fixed in accordance with definite rules; for example, if six readings are taken along a diameter, one observation has to be made at a distance of 0·044 pipe diameters from each wall. In a 6-inch pipe this means that the axis of the Pitot tube must be placed at a distance from the wall of just over $\frac{1}{4}$ inch, a position in which the outside of the standard Pitot head will only be about $\frac{1}{16}$ inch from the pipe wall. In pipes of less than 6 inches diameter the outside of the standard Pitot tube will be correspondingly closer to the walls of the pipe, and the flow there is likely to be seriously influenced by the presence of the Pitot, so that errors, probably mainly on the static pressure reading, may be expected.

Some alternative to the standard Pitot tube is therefore required for small pipes. The obvious method is to use a Pitot tube of considerably smaller dimensions, and satisfactory results have been obtained in this manner by the use of an instrument of the form shown in Fig. 46. Since for such small tubes the concentric construc-

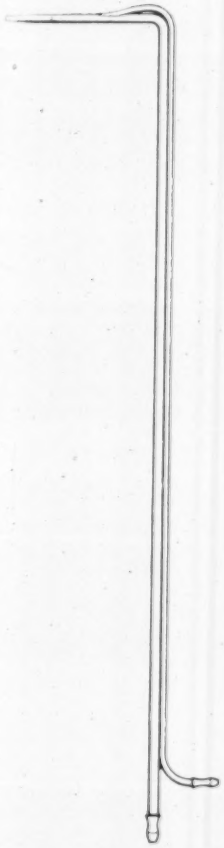


Fig. 46.—Small Pitot-static tube.

tion of the total head and static tubes presents some difficulty, the two tubes are here arranged side by side except for a short length in the head itself where the total head tube enters the static tube through the side, the junction being made air-tight by soldering. The mouth of the total head tube is about 0·03 inch in diameter, whilst the bore of the static tube is about 0·06 inch and the diameter of the static holes may be about 0·01 inch. An instrument of this kind must be calibrated before use, since it cannot easily be made geometrically similar to the standard Pitot-static tube.

The Total Head Tube. — The Pitot-static tube shown in Fig. 46 is an instrument requiring somewhat delicate workmanship in its construction. An alternative method of measuring the flow is to use a total head tube only, and to measure

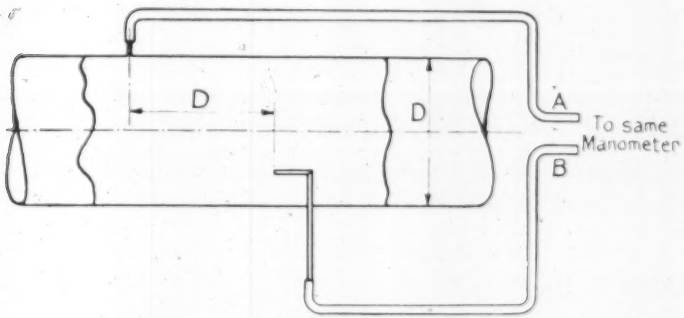


FIG. 47.—Measurement of flow with total head tube and side hole.

the static pressure separately. The advantage of this method lies in the fact that any tube with an open end facing the air current will measure total head accurately, no special shaping of the end in the stream being necessary. The outside diameter of this tube should not be greater than $\frac{1}{10}$ inch for measurements in a 6-inch diameter pipe, and should be even less for very small pipes. As regards the measurement of the static pressure, if the flow in the pipe is everywhere parallel to the walls, the static pressure is equal at all points in a section, and, further, it is found that a manometer connected to a small tube let in to the pipe so that its inner end is flush with the inside surface of the pipe, measures this pressure accurately. When, therefore, the flow is sensibly parallel, the velocity at a point in a pipe section can be determined by the arrangement shown in Fig. 47, in which the pressure leads A and B are connected to opposite sides of the same manometer, one side of which will be under the static pressure only, whilst acting upon the other there will be the sum of the velocity head and the static pressure. The resultant reading of the manometer will therefore

be the velocity head, and in order to measure the mean rate of flow the total head tube is traversed exactly as if it were a combined Pitot-static instrument. It will be observed that the total head tube in the diagram is traversed across a section situated about one pipe diameter downstream of the side tube, in order that the readings of static pressure may not be affected by the presence of the mouth of the total head tube when the observations are being taken near the pipe wall. The difference between the static pressures at these two sections one pipe diameter apart will never be sufficiently great to lead to any perceptible error in the measurement of velocity. It must be emphasised that the static pressure side connection to the

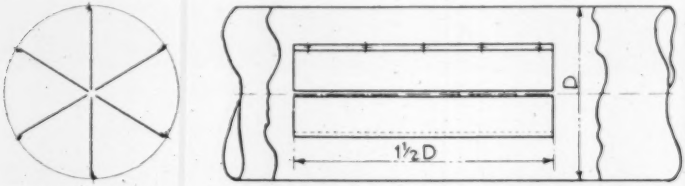


FIG. 48.—Flow straightening device.

pipe must be flush and smooth on the inside surface; all burrs made in drilling the hole in the pipe wall to take the small side tube must be carefully removed. The bore of the side tube should not exceed about $\frac{1}{8}$ inch.

If the flow at the section is not everywhere parallel to the axis of the pipe, the static pressure at the wall as measured by the side tube will not necessarily be the same as the mean static pressure across the section. Any rotary motion of the airstream, for example, will, on account of radial accelerations, cause the static pressure at the side hole to be greater than it is at the axis. The simplest method of straightening the flow sufficiently to make the static pressure at the section sensibly uniform is to introduce, some three or four, or preferably six, diameters upstream of the section, a flow straightening device, which may consist of six thin flat radial vanes reaching from the centre of the pipe to its circumference—see Fig. 48—and about one to one and a half pipe diameters in length.

This method will be found efficacious in most cases, except possibly if a sharp bend precedes the straightener. If this is so, and it is not possible to make measurements at some other section where conditions are more favourable, or to use the small Pitot and static tube, the best that can be done is to use in place of the single side tube for measuring static pressure, four or six such tubes equally spaced round the pipe circumference, and to lead the connections from these to a common air-tight reservoir, in which the static pressure will

probably be somewhere about the mean static pressure at the section. This reservoir may consist of a glass bottle with a neck sufficiently wide to take a large cork through which the necessary number of pressure connections pass; the pressure in the bottle is conducted through an additional connection to the manometer.

It will be evident that this method does not give the true velocity at each point at which the mouth of the total head tube is placed, even if the pressure in the reservoir is actually equal to the mean of the static pressures transmitted from the side tubes in the pipe. As, in addition, there seems to be some reason to doubt whether the pressure in the reservoir is exactly equal to this mean static pressure, it will be clear that this method of measurement is not one of the highest accuracy, although for most practical purposes it will give a sufficiently close approximation to the true rate of flow. When the velocity and static pressure both vary considerably across the section, the highest precision can only be obtained by a thorough exploration by means of an instrument such as the small Pitot and static tube already described.

The Shaped Nozzle.—Perhaps the most convenient practical method of measuring the mean flow in a small pipe is to introduce into it a shaped nozzle of the standard German type, or any other nozzle or orifice plate for which the coefficient is accurately known, and to measure the resultant pressure drop. The quantity flowing can then be calculated from the equations already given. This method is quite suitable in cases where a sufficient length of parallel pipe exists, upstream of the section at which the nozzle or orifice is inserted, for the flow at that section to have assumed the normal distribution for pipe flow.

Very often it is not possible to realise this condition, but in this case the same method may be used with a slight modification whereby advantage is taken of the uniform velocity of the jet leaving a shaped nozzle—a feature to which attention has already been drawn on page 100. A single observation of velocity head, taken with a Pitot-static tube arranged coaxially with the nozzle in the outlet plane, will give a good approximation to the mean velocity of the jet leaving the nozzle, and this velocity, multiplied by the area of the nozzle throat, will give the volume flowing. In cases where the highest accuracy is required, a preliminary exploration of the jet by means of the Pitot-static tube may be desirable in order to verify the constancy of velocity across the jet. A uniform distribution of this nature was only observed in the case of normal smooth pipe distribution of velocity upstream of the nozzle, and it is conceivable that if conditions here are very

widely different from the normal, a slight want of uniformity may occur in the jet. For most purposes, however, this refinement will be found to be unnecessary. If the nozzle can be conveniently placed at the outlet end of the pipe a further simplification is possible, since the static pressure in the jet will now be equal to that of the surrounding atmosphere, that is to say, zero, according to the convention by which atmospheric pressure is taken as the datum.* The total head at a point in the jet is therefore equal to the velocity head only, so that all that is required in these circumstances is a single observation of total head at the axis of the jet in the outlet plane of the nozzle. As we have already seen, this total head can be measured by any open-ended tube bent to face the airstream, and no specially shaped tube is now required. A thin-walled tube of about $\frac{1}{16}$-inch bore may conveniently be used. For the reasons mentioned above, a preliminary exploration of the jet may sometimes be advisable in this case also.

Mean Rate of Flow from a Single Observation.—A rapid and simple approximate method of determining the mean rate of flow when the distributions of velocity and static pressure at the section of measurement are fairly symmetrical, is to take a single velocity reading at the axis of the pipe. If a sufficient length of straight pipe exists upstream of the section in question, and the pipe is reasonably smooth internally, use may be made of the curve in Fig. 18, obtained by Stanton and Pannell, which shows the relation between the mean and the axial velocities for different values of $\frac{vd}{\nu}$. The axial velocity may be measured either by a small Pitot-static tube, or by means of the small total head tube in conjunction with a static pressure side hole in the pipe as described above. If doubt is felt as to the degree of smoothness of the pipe, or as to whether there is a sufficient length of straight pipe ahead of the section, instead of using the ratio of $\frac{v'_{mean}}{v'_{max}}$ from Fig. 18, the appropriate value of this ratio may be determined once for all by a preliminary careful exploration of the section by means of one of the standard methods already described. If the rates of flow which it is subsequently desired to measure vary over a considerable range, it will be advisable to conduct sufficient preliminary explorations at different rates of flow in order to establish the variation of the ratio $\frac{v'_{mean}}{v'_{max}}$ for the entire range of $\frac{vd}{\nu}$

* To avoid confusion, the reader is reminded that this convention is followed throughout this chapter.

that will be encountered. Some idea of the variation likely to occur in this ratio can be gained from Fig. 18; it will be seen that for high rates of flow the variation is relatively small, and the amount of preliminary exploration will be governed by the degree of accuracy that is desired. In some cases a single exploration at a rate of flow about half-way between the minimum and maximum likely to be experienced in practice may suffice.

This method may be used for large as well as for small pipes, provided favourable velocity and static pressure distributions exist. It is because a condition making for such distributions, namely, a portion of straight pipe some 20 diameters or so in length, is more usually present in the case of pipes of small diameter that the method finds its largest field of application for such pipes. This condition of a length of pipe upstream of the section of measurement is essential for a symmetrical distribution of velocity and static pressure in a pipe system on the blowing side of a fan, since, in general, all fans deliver the air in a very disturbed turbulent condition, and the flow close to the fan outlet very often does not fill the pipe symmetrically, but is, as it were, piled up to one side or another. On the suction side, however, three or four diameters of pipe upstream of the section may suffice, with a further 6 diameters or so between it and the fan inlet. Although the distribution of velocity at such a section will naturally not be of the type which we have termed the "normal" distribution, it will nevertheless usually be symmetrical and have a definite value for the ratio of mean to axial velocity, which can be determined by exploration as already described. A word of caution is necessary for this case. It will probably be found that the open end of the pipe acts to some extent as a sharp-edged orifice, that is, the airstream will contract and not fill the pipe completely for a short distance from the end. This effect can be very largely reduced by fitting the pipe with a shaped inlet, having an easy entry, as shown in Fig. 49 (*a*) and (*b*). The type illustrated in Fig. 49 (*a*) gives better conditions, but is somewhat more expensive to construct; either type may be made in wood and fitted to the pipe.

A modification of this method may often be found con-

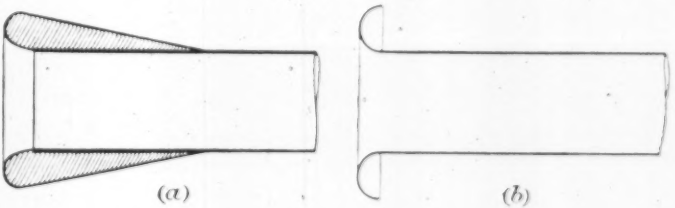


FIG. 49.—Types of shaped inlet to a pipe.

venient. Instead of determining the mean rate of flow from the axial velocity, the total head at the centre of the pipe, or the static pressure at a side hole, may often be utilised. If the flow at the section is parallel, each of these quantities will in many cases be found to vary approximately as the square of the air-speed, so that if P is either the total head or the static pressure at the section, and v_m is the mean rate of flow, we have

$$P = Kv_m^2 \text{ approximately,} \quad . \quad . \quad (1)$$

where K is a constant.

The value of K can be determined experimentally by measuring simultaneously v_m, by one of the methods already described, and P for various rates of flow. Once K is established, v_m can be calculated from an observation of P.

It will be useful to examine this method in greater detail. Let us confine our attention to a section X in a given length of pipe AB having a fan at B, which may either be made to blow from B to A or to exhaust from A to B. For simplicity imagine also that there is a shaped entry at A. We shall assume initially that the velocity across the section is uniform and equal to v_m. Let O be a point in the undisturbed atmosphere where the air is at rest (Fig. 50).

If we neglect the commencement of the motion when the fan is starting up, and confine our attention to steady conditions when the flow is established and proceeding at a constant rate, we see that the only work done is that against friction, either between the moving air current and the pipe walls or between adjacent particles of air moving at different rates, and the energy equivalent of the internal losses in the current itself due to turbulence. These may be grouped with the frictional losses, since they are inseparable from the flow. We may regard the flow as a complete circuit which commences and ends at the point O in the external atmosphere. The

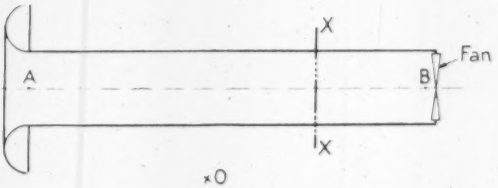


FIG. 50.

air starts from rest, acquires a velocity v_m in the pipe, and is returned to a state of rest. (We shall neglect internal losses in the fan itself.) The change of total head between any two sections of the circuit is equal to the energy loss per unit volume between those two sections.

(*a*) **Fan Sucking Air from A to B.**—Assume that at A, just inside the pipe inlet, the air has acquired its velocity v_m.

At O the total head, velocity head, and static pressure are all zero (the atmospheric pressure is taken as the datum according to the usual convention). Between O and A there is a certain loss of head f_1, due to friction between moving and still air, and at A the air has acquired its velocity v_m. The total head at A therefore differs from that at O only by the amount f_1, and is therefore equal to $-f_1$. Bernouilli's equation (which states that, apart from energy losses, the total head is constant), when applied to the portion OA of the circuit, shows that the static pressure at A is $-\frac{1}{2}\rho v_m^2 - f_1$, since the velocity head is $\frac{1}{2}\rho v_m^2$ and the total head $-f_1$. Between A and X there is an additional energy loss f_2 due to the frictional resistance of the pipe between A and X,* and the static and total heads at X may again be determined by the application of Bernouilli's equation. We obtain in this manner

$$\text{Total head at X} = -(f_1 + f_2),$$

and

$$\text{Static pressure at X} = -(f_1 + f_2 + \tfrac{1}{2}\rho v_m^2),$$

the negative signs indicating that both these pressures are less than atmospheric.

Now f_1 is always found to be very small compared with the other pressures, so that we may say that

$$\left.\begin{aligned}&\text{Total head at X} = -f_2,\\ \text{and}\quad&\text{Static pressure at X} = -(f_2 + \tfrac{1}{2}\rho v_m^2)\end{aligned}\right\}\text{approximately.}$$

Moreover, if there is a shaped entry at A, the quantity f_2 will not differ appreciably from the frictional resistance of the length of pipe between A and X, and this will be related to the mean rate of flow according to equation (4) on page 40. Although this frictional resistance does not vary exactly as v_m^2, the error made by assuming that it does so vary will not be large even over a fairly wide range of speed, and for most practical purposes we may therefore take both static pressure and total head at X to vary as the square of the speed, so that equation (1) is established for the case where X is on the suction side of the fan. Usually f_2 will be found to be considerably smaller than $\frac{1}{2}\rho v_m^2$, the velocity head. For the rates of flow for which the method of measurement under consideration can be used, that is to say for which the pressures are of sufficient magnitude to be measurable with the necessary degree of accuracy, the section X will have to be something like 50 pipe diameters

* f_2 includes any losses due to the inlet, these are small if there is a shaped entry to the pipe at A

from A before the frictional resistance of the length AB becomes equal to the velocity head. As X will usually be considerable nearer than this to A, it follows that at a section on the suction side of a fan the total head is in general small, and the static pressure somewhat greater than the velocity head. Hence if this method of measurement is adopted it is preferable, on the suction side, to utilise the static pressure as a measure of the speed, either by adopting an expression such as (1) on page 141, or by plotting a curve between the static pressure and the velocity. It should be noted that, since the portion f_2 of the static pressure is usually less than $\frac{1}{2}\rho v_m^2$, the error due to the assumption that the static pressure varies as v_m^2 is correspondingly reduced, as it only affects the smaller part f_2.

The conclusions to which the reasoning has led will not be invalidated if there is no shaped entry at A; the effect of this will simply be to alter the value of K in equation (1).

(*b*) **Fan Blowing Air from B to A.**—We are again concerned only with the length XA of the pipe. Assume that the mean rate of flow is v_m as before.

At A the air will have a velocity head $\frac{1}{2}\rho v_m^2$ and the static pressure referred to the atmospheric pressure will be zero, so that the total head at A will be $\frac{1}{2}\rho v_m^2$. The resistance of the length AX will of course be f_2 as before (f_2 does not now, however, contain anything equivalent to the inlet loss of the previous case, and so will have a slightly different value), so that the total head and static pressure at X will both be higher by f_2 than they are at A. Thus

$$\text{Static pressure at X} = f_2.$$
$$\text{Total head at X} = f_2 + \tfrac{1}{2}\rho v_m^2.$$

Following a similar line of argument to that previously adopted, we arrive at the conclusion that in this case, i.e. when X is on the delivery side of the fan, the total head, being greater than the static pressure, should be taken as a measure of the speed, and that it varies very nearly as the square of the speed.

In both cases (*a*) and (*b*) the assumption has been made that the velocity v_m is uniform across the section. Actually, of course, it is not, but the effect of this will merely be to alter the value of K in equation (1).

THE HANDBOOK OF INDUSTRIAL INSTRUMENTS

M. F. Béhar*

CHAPTER XV

Speed and Acceleration

(*Continued*)

15. Electric Tachometers

This class comprises tachometers which employ generators or magnetos together with various types of electrical instruments calibrated in rotational or linear speed units. It includes neither chronometric electric tachometers nor electric frequency meters. The former are described in Section 6; the latter in Section 20 (the first of three sections dealing with instruments primarily designed for measuring *frequency* rather than rotational or linear *speed* as generally understood). Even with these exceptions, the electric class includes a surprising number of different types. Most of these types have failed to pass from the laboratory to the plant, and they can be omitted. The commercial types, readily available on the market, are fewer, but instead of undertaking to describe all these types separately, a greatly summarized discussion seems preferable. Some commercial types or models, as a matter of fact, have been so highly specialized and elaborated that their applications are extremely limited.

Characteristics

(1) Electric tachometers measure speed continuously. They do not integrate or give the average speed over successive definite periods of time as do chronometric tachometers, but measure instantaneous speed and are therefore capable of indicating variations in the measured speed.

(2) They are capable of indicating and/or recording rapid fluctuations; but the industrial indicating and recording instruments are purposely damped in order that the pointers of the former will not wobble and that the records produced by the latter will not be blurred. (Special instruments designed for the study of extremely rapid fluctuations in the speed of machinery are not considered, in this discussion, as being industrial electric tachometers.)

(3) The measurement of speed with electric tachometers is inferential but the relation between speed and the utilized effect thereof to which the electrical instrument responds is usually a straight-line relation, so that accuracy and other measuring properties are largely dependent upon the instrument itself.

(4) Linear characteristics of most generators make it possible to scale instruments uniformly from zero to maximum readings. This is of con-

*Engineering Editor

siderable importance with regard to the calibration of both indicators and recorders and it is of extreme importance with regard to the accuracy and reliability of records—produced of course on printed charts.

(5) The range of any one electric tachometer can be very wide. It starts at zero and the accuracy of the various methods does not depend on the speed being measured. Nevertheless it must be borne in mind that the measuring instruments are electrical instruments and that—especially in the case of indicating voltmeters—such instruments are preferably used in the upper sixty percent of their scale ranges. The generators should not be driven at excessive speeds. The safe limit is usually stated by each maker. The range of any one system may be changed readily, by means of various devices either furnished with the tachometers or obtainable separately.

(6) The instruments themselves, being standardized electrical instruments, are obtainable in many forms and sizes. They are thoroughly understood by electricians. They are usually subject to the errors common to most electrical instruments: stray magnetic fields, variations in torque of restraining springs, possible friction of moving system, loss in strength of permanent magnets, and miscellaneous effects of vibrations or of temperature fluctuations.

(7) It is possible to connect a plurality of instruments to one generator, and easy to change instruments at will. Fig. 546 (Brown Instrument Co.) shows for example two models of indicators and one recorder simultaneously actuated by the same generator.

(8) The possibility of locating the instruments at long distances from the generators is the best-known characteristic of electric tachometers. The Brown Instrument Co. states that instruments can be located "at any distance up to approximately five miles." It must be borne in mind that the resistance of most conductors varies considerably with temperature—especially that of copper conductors which are almost universally used as leads between generators and instruments on long-distance installations. To minimize as much as possible this source of error, the manufacturers have brought out D.C. tachometers in which the total-circuit resistance is so high that the copper lead resistance becomes a minor factor. Several methods are employed. One involves high-resistance instruments—it increases, however, the temperature error of the instrument itself and makes it less easy to connect one or more instruments at will without altering the calibration of each. Another method, more generally employed, involves high-resistance generator armature windings and also a large series resistance in the circuit. This method is favored by most makers, the generators consequently generating usually six volts on open circuit per 1000 r.p.m. but only about five milliamps. Such methods are necessary with voltmeters for instruments, but with potentiometers there is no necessity for compensation or minimization of changes of resistance in the connecting circuit due to temperature. (See No. 13 below for some other characteristics peculiar to the potentiometer method.)

(9) Direction of rotation is immaterial with most generators of industrial electric tachometers. The voltage-speed relation is the same in both direc-

tions. This makes it possible to employ indicators and recorders with zero-center scales, which are desirable in the land and water transportation industries and on some plant applications as well.

(10) The effects of wear on accuracy are usually negligible. In a statement prepared for this chapter by the Bristol Company it is said that "accuracy does not change with use because wear on the bearings of the magneto has no effect on the voltage generated."

(11) Repairs and replacements can usually be readily made on the unit parts of an electric tachometric system because according to Huey of "the basic similarity to other electrical apparatus."

(12) The generators of most modern industrial electric tachometers are light in weight and occupy little space. They can readily be installed directly on apparatus, without necessarily being driven by flexible shafts. There are various models of protective cases, such as dust-proof, moisture and fume-proof, completely water-tight, magnetic shielding, etc. The industrial generators or magnetos require little attention, but when such troubles as improper brush fit, dirty commutator, etc., develop, they cause serious errors which frequently are not detected and cannot be detected without careful inspection or checking against the Plant Standard tachometer.

(13) *Potentiometers.* With the potentiometer measuring circuit there are certain distinctive characteristics. Among these may be mentioned the following, extracted from a statement furnished for this chapter by the Leeds & Northrup Co.

A potential is set up in the recorder equal and opposite to that generated in the magneto. The null balance galvanometer is used to detect any difference between the magneto generated potential and the opposing potential of the measuring instrument. If, following a speed change, there is for an instant a potential difference, the recorder galvanometer immediately detecting the unbalance directs the recorder mechanism in the standard L. & N. manner to increase or decrease the opposing potential. The position of certain portions of the recorder mechanism in order to equalize the opposing potential to the magneto potential is used as a measure of the tachometer speed since it is a direct function, and a pen actuated by the recorder mechanism accurately scribes the speed curve on a legible chart of nominal 10" width. Inherent advantages of the Potentiometer method of measuring speed in common with other measurements using this circuit are as follows:

a. Due to a negligible flow of current between the magneto and recorder, the resistance of the connecting two-wire circuit does not have to be considered in the calibration of the recorder.

b. Accuracy of measurement is practically independent of variable brush contact resistance in the magneto and other internal magneto resistance.

c. Recorder may be moved in distance from the magneto at any time without recalibration on account of its practical independence of lead resistance.

d. Circuit permits the use of the mill type galvanometer not requiring calibration, which is the most accurate known type.

e. The only sensitive moving part (the galvanometer) is easily replaced without affecting the calibration.

To which it must be added that a potentiometer recorder is of necessity more expensive and more complicated than the usual industrial recording voltmeter. Nevertheless, the fact that the potentiometer method is the most accurate often outweighs such considerations.

(14) *Alternating Current Types* of electric tachometers possess one or two distinctive characteristics which make some of the above remarks inap-

plicable to them. There are few A.C. tachometers in use as compared with the D.C., and the following (abstracted from Huey's A.S.N.E. paper) applies only to the particular type which appears to be of the greatest industrial interest, namely, the system comprising a magneto type generator and a wattmeter type instrument:

The generator is of the so-called magneto type, for the reason that it is self-excited by means of permanent magnets in the form of a multipolar rotor. This rotor rotates in the air gap of a series of projecting stationary fixed poles, on which are wound alternately, voltage and current generating windings. The poles of these two separate windings are electrically

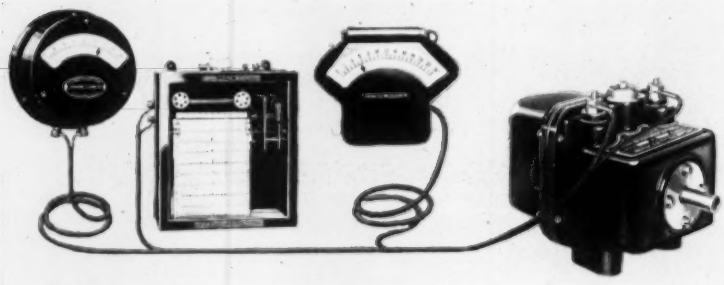


Fig. 546

spaced, so that the currents generated by the revolving magnet poles are 90 degrees in phase difference. The wattage power delivered by the generator, in combination with the adjustments of the indicator, is regulated to be directly proportional to the speed of the generator. The dial of the indicator is calibrated in equivalent r.p.m. The indicator is of the single-phase alternating current wattmeter type, operating on the induction principle, practically similar to the commercial types with one major exception: In the commercial meter the torque of the moving element, which is a hollow aluminum cup, is produced by the magnetic drag of a rotating field set up by the current and voltage windings on the core at 90 degrees displacement, when indicating the watts input at 100 per cent power factor. This phase displacement is obtained by the design of the instrument. In the tachometric system the necessary phase displacement is obtained in the design of the generator, thereby simplifying the construction of the indicator by virtue of the generated phase relation. Separate windings are employed on the generator for the operation of multiple indicators, and the connection is made to each indicator by means of three leads, one of which is common to the generated two-phase currents. By employing a geared-up, indicating hand, on the indicator, the graduations of the dial extend over a large arc.

Advantages: (1) Commutator or brushes are not employed in the design of the generator. (2) By employing multiple circuits on the generator, the indications of one indicator are not affected by the placing of other indicators on a multiple indicator installation. (3) No revolving windings on generator. (4) Well defined scale markings on indicators at all speeds. (5) Indications closely follow changes in shaft speeds. (6) Suitable for remote indication. (7) Multiple indicators may be employed.

Disadvantages: (1) Calibration affected by deterioration of strength of permanent magnet employed in generator. (2) Calibration affected by changes in operating and ambient temperature caused by ohmic variations in the copper circuits. (3) Accuracy of indicators is affected by stray magnetic fields, vibration and control spring variation in the moving element.

(15) *Squirrel-cage Type.* This form of electric tachometer likewise possesses distinctive characteristics, among which the outstanding one is that it is a self-contained instrument the pointer of which is attached to a soft iron vane pivoted inside the rotating squirrel-cage itself. This instrument is little known in the United States.

Industrial Models

A few brief descriptions, emphasizing recent developments—the makes appearing in alphabetical order.

Bristol Company—This firm's round-chart recorder, Fig. 505 (in Section 1 of this chapter), produces records on 8-inch charts with $2\frac{1}{4}$-inch scale length, rotation period 3, 6, 10, 12 or 24 hours. The scales read r.p.m., f.p.m., yds.p.m., etc. These charts have a sensitized carbon-coated surface on which the stylus leaves a clear-cut white record line. On removing the chart from the instrument it is dipped in a fixative solution which makes the record permanent. This method reduces friction, which is essential because of the sensitivity of the Weston voltmeter movement embodied in this recorder. The strip-chart recorder, Fig. 506, uses six-inch charts, with a $5\frac{1}{4}$-inch scale. The charts come 90 feet long and when driven at the standard speed of one inch per hour furnish a 45-day record. Other chart speeds are 3 or 6 inches per hour, also 1, 3 or 6 inches per minute. The pen-arm swings above the chart, the pen does not come quite in contact with it, and the ink makes the record by capillary attraction. Duplex and multiple-record instruments are also furnished—the latter of course using multi-color ribbons instead of ink. (See Chapter VI, recording pyrometers.) In addition to the recorders, various standard forms of Bristol electrical indicating instruments are available. The generator listed with Bristol recorders or indicators is the Weston Model 44. See below.

Brown Instrument Co.—All tachometer instruments of this make have a sensitivity of 400 ohms per volt (0.0025 ampere for full scale deflection) and are therefore interchangeable. In Fig. 546, from left to right: (1) Round form indicator, eight-inch aluminum case. (2) Single-record recorder. This type has a chart in one section (scale $6\frac{1}{4}$-in. wide) but other models are capable of producing up to six records. The charts are 100 feet long. The marking medium in the form of a ribbon lasts two months before renewal. With duplex charts (same width but each scale 3 inches wide) records from as many as 12 tachometric generators can be produced—six on each section of the chart. (3) Twelve-inch illuminated dial indicator "particularly recommended for use in industrial plants." Hundreds usually omitted from scale figures. Not shown: edgewise type indicators. The generator listed with Brown recorders or indicators is the Weston Model 44. See below.

The Electric Tachometer Corp. ("*Tetco*")—This maker's chronometric-electric recording tachometer was described above, in Section 6. The generators of this make are used by Leeds & Northrup, Westinghouse and other instrument firms in making up electric tachometric systems. Also, "Tetco" tachometers are supplied with instruments of various other makes when particular designs are called for.

Though not new, one of the "Tetco" electric tachometers seems to merit inclusion here because, unlike other electromagnetic systems, it is fully portable and can even be used as a cut-meter. Fig. 547 shows the entire outfit and part of the carrying case. "The hand-magneto (weight $2\frac{3}{4}$ pounds) is of extremely rugged design and consists of a small generating unit, connected through a triple gear combination to the front spindle. The gear ratios are the same as the ratios of the indicator scale-ranges . . . All case castings are aluminum . . . All gears are phosphor bronze or steel with fine pitch teeth and wide faces, giving smooth and noiseless operation . . .

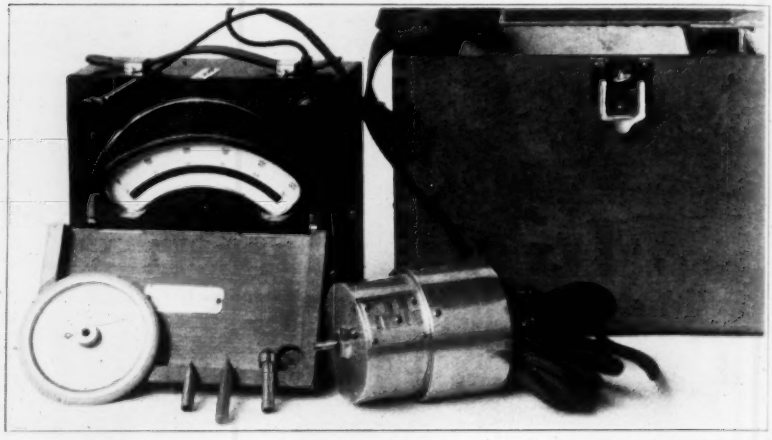


Fig. 547

The indicator is of the horizontal type, with hair-line needle and mirror scale; it is dead beat and not affected by external electrical influences. . . . By separating the generating and indicating elements, absolutely steady readings can be obtained, a feature not found in tachometers of the mechanical type."

The generators of this make have all been developed especially for speed-measuring applications and various refinements have been added in the course of the last twenty years. The newest is the Model M-800, a vertical type with gear box. Its main feature is the absence of commutator end bearing. It—and some others—are described in the following résumé (prepared jointly by engineers of The Electric Tachometer Corp. and of the Westinghouse Elec. & Mfg. Co.) from which only a few condensed extracts can be given:

. . . The selection of a magneto for indoor testing use is often determined by the driving arrangement. For speeds up to about 3500 r.p.m. maximum an open spur gear drive with magneto M-100 is most economical and entirely satisfactory. For higher speeds the spur gears are noisy and would require an expensive oil-tight housing. A worm gear is, therefore, used with a vertical shaft magneto type M-800. The worm gear with casing is economical in cost and quiet. The great reduction in speed, however, necessitates a larger magneto to insure accuracy and steady readings at the lower end of the scale.

For most industrial plant purposes such as mills, central stations, etc., the tachometer equipment must be much more rugged than for testing applications and must be designed for long periods of continuous operation without attention. The selection of the magneto is also determined to a great extent by the kind of driving arrangement which must be provided. For gears, couplings or belts, the M-200 type has been found satisfactory. This has a ½" shaft with a double ball bearing at the gear end.

A chain drive has been found to impose very severe loads on the magneto. In order to have a long life a fairly heavy chain must be used. If not properly installed or allowed to get loose, this chain will climb the sprocket and will either bend or break any ordinary shaft which could be built into a magneto of reasonable size. To overcome this difficulty the M-300 magneto with a floating shaft was designed . . .

Both the M-200 and M-300 magneto are totally enclosed with gaskets and water tight outlet boxes for conduit connections. The cases are of non-corrosive alloys.

For railway and marine service, Tetco tachometers are extra-heavy, water-tight, able to withstand severe temperature changes and operate continuously while exposed to the weather. The Westinghouse indicating instrument, type DXA, is used . . . Calibrating adjustment can be accomplished without opening the instrument . . . The moving element will operate successfully when mounted directly on a locomotive gage board. Extreme

Fig. 548

temperature changes or vibrations do not interfere with its performance.

Wherever possible a vertical magneto type M-800 is used. This is . . . quickly cleaned, and so designed that water due to condensation . . . will not cause trouble. Excessive lubrication will not . . . affect successful operation. It has been found through experience that railway and marine engineers and maintenance men will excessively lubricate any moving mechanism, even though prominent warnings are displayed on the unit itself . . .

. . . Alloys of gold have been developed for commutators and brushes, which will operate satisfactorily without lubrication, and which will also permit sufficient brush tension to cut through a considerable amount of grease which may get on the commutator due to over-lubrication. These alloys also are such that grease, moisture or fumes from chemical plants will not cause corrosion of brushes or commutator . . .

Another new "Tetco" tachometer is a combination outfit of which the instrument end is shown in Fig. 548 which is almost self-explanatory. The tachometer is a generator-voltmeter type, and the counter is actuated by a contactor. The counter unit is said to be unique in that there are no ratchets or escapement mechanism in the unit. It is actuated by a patented electromagnetic follow-up motor. This motor is said to give the fastest long distance count of any device on the market for this purpose—3000 counts per minute. Experimentally it has been operated at 6000 counts p.m. continuously without error.

Esterline-Angus Co.—This firm has just brought out a highly developed generator, Fig. 549. Some of its features are as follows:

The generator is designed for heavy mill type work, and requires no additional protection or mounting parts for heavy duty work. The output is 13 volts at 1000 r.p.m. of the armature, making it possible to use maximum amount of zero temperature coefficient metal in the instrument circuit, and thus reduce the temperature error.

The design of the armature and commutator is such as to give a steady voltage output at relatively low speeds. The armature can be driven at or near 1000 r.p.m. when the generator shaft itself is connected to any speed ranging between 200 and 5000 r.p.m. The drive is through a separate jack shaft on large bearings taking the strain off the armature bearing, and at the same time making it possible to have interchangeable gears, so that direct connection can be made to any shaft running between 200 and 5000 r.p.m

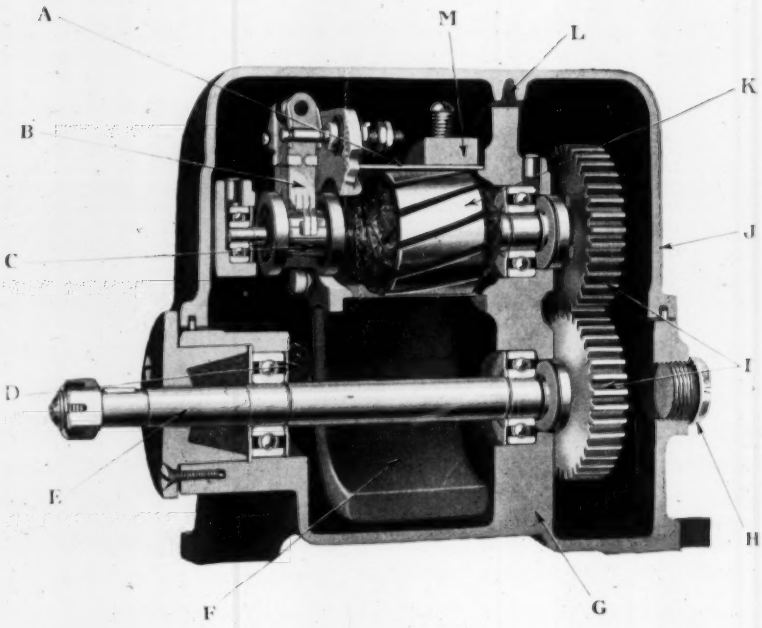


Fig. 540

The available gears are 1-1, 2-1, 3-1 and 5-1 in both directions. Such an arrangement eliminates the necessity for outside drives such as belts, gears, pulleys, chains, and their respective guards and mountings, thus reducing the cost and making a complete and compact installation. The case is fume- and moisture-proof, equipped with suitable connections for conduit.

Other features are described in the following, condensed from the maker's description:

A. Non-magnetic shield protecting air gap from foreign materials. B. Brushes, which can be removed for cleaning or replacement without use of tools. Design eliminates vibration. C. Twelve glass-hard commutator bars set in linen base micarta insulation. D. Screw terminals. Can be removed and ½" conduit screwed into case for wiring. E. Heavy drive shaft on large ball bearings. F. Magnet of large cross section. G. Aluminum case with one gasketed joint. H. Screw cap which enables checking of drive shaft speed with revolution counter. I. Drive gears, steel and Formica, protecting armature from shock and driving shaft strains—Changeable ratios as described above. J. Light cast aluminum cover. K. Laminated armature ground to size and skewed one slot to eliminate pulsating voltage. Windings impregnated with elastic varnish. Tested at 2,000 volts. L. Packing separating gear compartment from generator. M. Magnetic shunt for adjusting calibration of generator. Gives 10% adjustment plus or minus.

The recorders are standard Esterline-Angus direct current recording voltmeters, calibrated for use with the generator, furnished in five types of cases: portable, wall and switchboard single instruments, and wall and switchboard type twin cases which contain two recorders. In twin-type cases, speed recorders can be combined with other types of instruments. Cases are made of cast aluminum finished in black enamel.

Five standard methods of driving the chart are available: (1) Spring-driven clocks—hourly chart speeds of ¾, 1½, 3, 6, or 12 inches per hour.

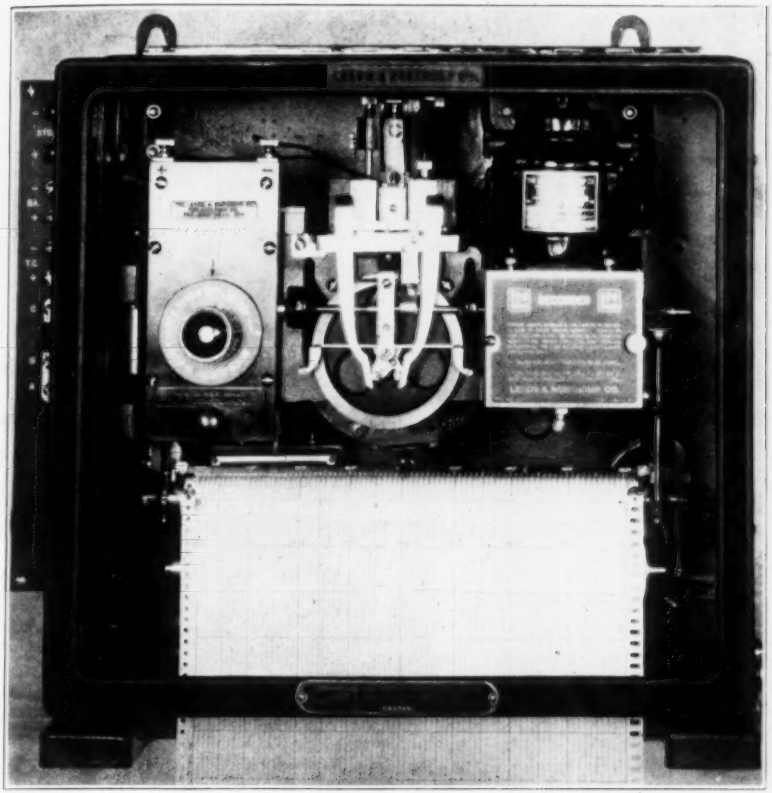


Fig. 550

(2) Spring-driven clocks—hourly and minute chart speeds of $\frac{3}{4}$, $1\frac{1}{2}$, 3, 6, or 12 inches per hour and per minute. (3) Impulse-driven clocks—$\frac{3}{4}$, $1\frac{1}{2}$, or 3 inches per hour. (4) Synchronous clock drives—$\frac{1}{4}$, $1\frac{1}{2}$, 3, 6, or 12 inches per hour. (5) Motor drives—$\frac{3}{4}$, $1\frac{1}{2}$, 3, 6, or 12 inches per minute, or per second.

The measuring elements used in the recorders are standard D'Arsonval D.C. voltmeters, similar to those used in all Esterline-Angus D.C. voltmeters. The recorders have removable writing pens and inkwells. Charts are 90 feet in length, six inches wide, printed in two colors.

Indicating instruments are 9-inch round types, either wall or switchboard mounting. The indicators as well as the recorders are calibrated for use with the generator with which they are to operate.

Leeds & Northrup Co.—This firm makes potentiometers and supplies either Weston or Electric Tachometer Co. generators. The distinctive characteristics of the potentiometer method of speed measurement (really *voltage* measurement) were outlined above. The L & N instruments for this purpose differ little from their recording pyrometers, etc. Fig. 550 shows the usual model. Scales are uniform, 10 inches wide with rectangular

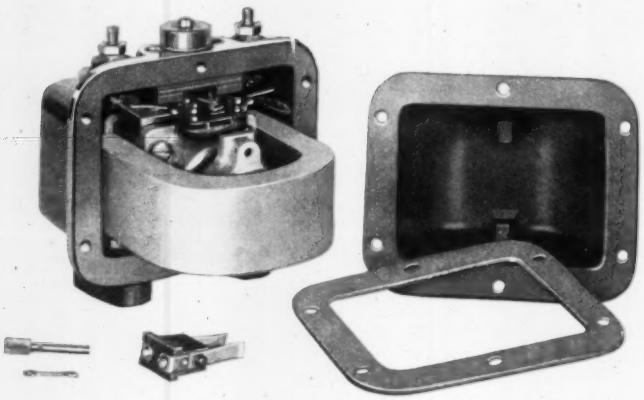


Fig. 551

co-ordinates. Standard paper speed is 3 inches per hour, $1\frac{1}{4}$ and 6 inches optional. Charts come in 150-foot rolls. Single-record instruments are curve-drawing and produce ink records. Multiple-record instruments (as many as 16 records) employ a metal stamp printing device, each record consisting of a series of dots with an identifying number beside it. Models are structually alike except in the automatic switch and the printing device. Multiple-point instruments—whether potentiometers or voltmeters—should only be used on steady-speed applications on account of the interval between successive connections to each measuring circuit. The accuracy of potentiometers is extremely high. They are used on important applications. Extracts from a recent letter on this subject:

> . . . The principal class of applications . . . has been in connection with power plants . . . of particular value in bringing large turbo-generators up to speed. The warming-up of a turbo-generator requires several hours. Nearly all of the large machines have a critical speed at which it would be dangerous to permit the generator to rotate for any length of time . . . In warming up the turbo-generator, care is taken to bring the machine quickly through the critical speeds to prevent damage. The record . . . is of interest to the power plant operating engineer . . . At regular intervals, the turbo-generators are run over speed to check the over-speed tripping devices. These are usually centrifugally-driven cut-outs which operate on speeds 8 to 10% above rating (I believe that the GE trip is at 10% over speed, and the Westinghouse at 8%). The speed recorder will show, of course, when the over-speed trip operates.
>
> . . . Another important application is . . . the speed of the rolls in paper mills . . . [Also] the measurement of differential speed between successive rolls. The purpose of this is to hold at a constant value the differential speed between rolls so as to prevent paper breakage . . .

Sperry Gyroscope Co., Inc.—A high-voltage system recently developed especially for naval service and already installed on vessels of all classes. The indicators are all large and each combines a revolution counter which logs the total turns of the propeller shaft from which it is operated. The contactors for operating these counters are built into the generator assemblies. The generators are hence called "transmitters." There are several other special features, including optional provision for flashing a light once for each turn of the propeller. "On the bridge these lights are mounted out in the open and greatly assist in bringing the vessel alongside the dock." This idea may suggest production control applications around industrial plants.

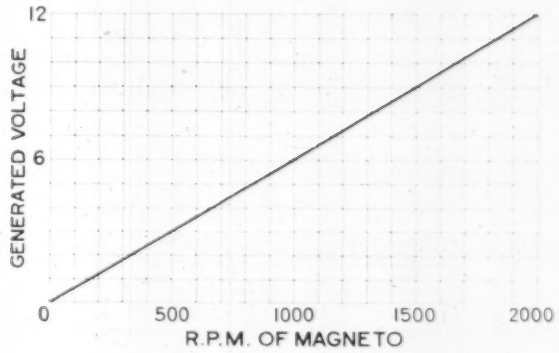


Fig. 552

Westinghouse Electric & Mfg. Co.—This firm makes only instruments for electric tachometers. Some were referred to above under Electric Tachometer Corp. In a statement by this latter concern the following appears: "While these instruments are essentially voltmeters, they are made with specifications as to damping, internal resistance, current characteristics, etc., demonstrated . . . to be the most suitable for tachometers . . . guaranteed to be accurate within one per cent of full scale—at any part of the scale—under normal operating conditions. This covers the entire tachometer, generator and indicator. Not less than 10, and as many as 20 points, are calibrated to extreme accuracy on every individual scale."

Weston Elect. Instrument Corp.—This maker's Model 44 magneto is a D.C. generator having a permanent magnet field and a revolving armature provided with a commutator and two brushes. The distribution and uniformity of the magnetic flux is governed by pole pieces of proper shape and the permanency of the magnetic circuit is obtained by a small air-gap and thorough aging of the magnetic system. The brushes and commutator segments are constructed of a hard non-corrosive alloy. The brushes are carried on a self-aligning holder which equalizes the pressure on both brushes and so arranged that the brushes may be easily removed and replaced. The armature is chord-wound on a laminated iron core mounted on and keyed to a tool steel shaft carried in ball bearings. The armature pole pieces, bearing housings, bearings, brush holder and resistance coil are all assembled in a unit which is mounted in an aluminum die-cast case. The case is closed by an aluminum die-cast cover. Fig. 551 shows this generator partly dismounted. Fig. 546 shows the outside view.

The magneto is designed to generate an emf of 6 volts per 1000 r.p.m. and is adjusted to have an internal resistance of 20 ohms. It is designed to operate at a current output up to .05 amperes. The speed-voltage curve is a straight line and is shown in Fig. 552.

The terminal voltage may be adjusted under different conditions of instrument load by means of a magnetic shunt which can be operated from the outside of the case, and which allows a range of adjustment of the terminal voltage of 8 percent each way. The generator speed corresponding to full scale deflection of the instrument should be kept between 1000 and 2000 r.p.m. There are practically no errors due to temperature in the magneto itself. The accuracy of this generator is guaranteed to be within 1% at all times if properly installed. It is said that the accuracy is appreciably better than this under average conditions.

The Weston instruments used as part of tachometer equipment are voltmeters of the permanent magnet movable coil type, having scales calibrated according to the class of service. The instruments are all indicators. They have a resistance of 500 ohms per volt, corresponding to a current of .002 ampere, for full scale deflection. This makes it possible to operate as many as twenty instruments from one generator. The high internal resistance of the instrument tends to make the accuracy of the readings independent of the size and length of the connecting cables, poor connections, etc. The resistance coils in the instrument are constructed of manganin wire which has a negligible temperature coefficient. This eliminates temperature errors because the resistance of that part of the circuit having a temperature coefficient (magneto armature and connecting cables) is a small part of the total resistance.

Fig. 553

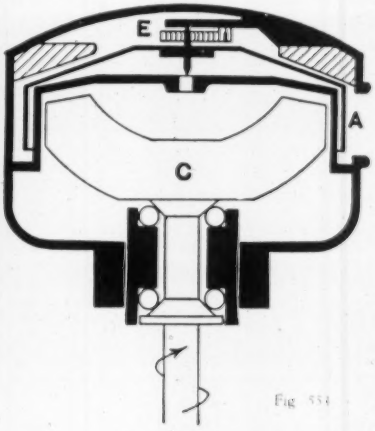


Fig. 554

The accuracy of the instruments is guaranteed to be within 1% of full scale deflection, except one small model which has an accuracy of 2%, and one model which has an accuracy of ½ of 1%.

These Weston indicating instruments come in ten models (probably more at this time) most of them of familiar appearance to engineers: flush types, square-case, fan-shape, round-case in various sizes, water-tight case, etc. One new model is illustrated here (Fig. 553) to show the latest improvement which is the scale covering 270° of arc, as against the usual 120° arc of electrical indicating instrument scales. The dial diameter is 2¾ inches.

16. Magnetic Drag Tachometers

With more than forty million automotive vehicles in operation throughout the world—about twenty-five million of them in the United States—it is natural that this class of tachometers should be the most widespread. But while it is represented by millions of instruments in automotive service, its penetration of the industrial plant field has so far lagged behind that of other classes. One reason is that most of the other classes were improved and brought to a state of high and specialized development (as regards intrinsic accuracy) before the magnetic tachometers were made accurate enough to compete for the favor of industrial engineers, or even to deserve

their consideration. The temperature error was the biggest obstacle: in the case of an uncompensated instrument, it amounts to not less than four percent for every 10°F, but let it be said immediately that this particular source of error has been reduced to about 0.2 percent per 10°F in high grade compensated models.

The principle of speed measurement is based on the fact that if a magnet is rotated near a metal disk this latter will tend to rotate in the same direction by reason of the eddy currents induced in the disk by the motion of the

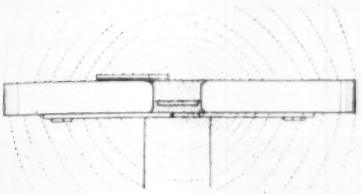


Fig. 555

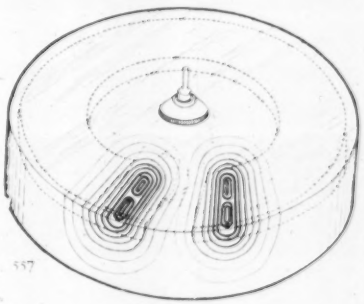


Fig. 557

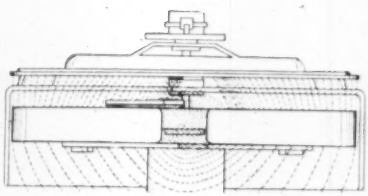


Fig. 556

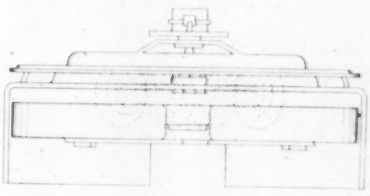


Fig. 558

magnet, which eddy currents in turn set up magnetic fields. In Fig. 554 (from Diederichs & Andrae) C is the rotating magnet attached to the end of a vertical shaft, A is a metal cup pivoted co-axially with the magnet, and E is a coiled restraining spring. Cup A is usually made of aluminum and is graduated on its rim, a section of which is viewed through a small window. Fig. 554 represents the original Warner instrument. In the Stewart instrument the bar magnet was replaced by a circular magnet in the form of a ring with one gap. The more recent Stewart-Warner instruments retain the circular magnet. Figs. 555 to 558 show in some detail the application of the principle. Fig. 555 is an edgewise view of the magnet and shows its lines of force. Fig. 556 illustrates the flux from different portions of the magnet through the cup and field plate, the effect of the latter being to increase the flux through the cup several hundred percent. The main eddy currents induced in the cup are shown in Fig. 557. Only the principal eddy currents are shown. Lesser ones flow in other parts of the cup. All of these eddy currents travel around the cup in the same direction of rotation as that of the magnet (which is shown in dotted lines). Each of these eddy currents sets up a field of its own. Fig. 558 shows the lines of force thrown out by the two main eddy currents and omits for the sake of clarity the lines of force from the permanent magnet. It is the pull exerted by the magnet field upon these eddy current fields that makes the cup tend to rotate. The faster the

magnet rotates the greater are the eddy currents and the stronger their magnetic fields; hence the stronger the drag of the magnet on the cup. Except as it is altered by temperature compensating devices, etc., this torque is directly proportional to the speed of the magnet.

Characteristics

(1) Inexpensive, small, light, self-contained tachometers of this class are practicable.

(2) Inferential principle; secondary method.

(3) Continuous measurement of instantaneous speed.

(4) Wide ranges, starting close to zero. Scales can be graduated uniformly. Range of each instrument cannot be changed without external devices such as change gears. These are seldom supplied.

(5) Temperature error considerable except in highest grade models. Seldom less than 0.03% per deg. F.

(6) Position error varies with each individual instrument. Imperfect balance of "speed cups" that have been handled increases this error considerably.

(7) Accuracy seriously impaired when friction develops at cup pivots.

(8) Accuracy of imperfectly shielded models impaired by stray magnetic fields.

(9) Repairs and adjustments should be made by manufacturers, but service stations abound in industrial districts.

(10) Principal application is automotive field but some models are quite suitable for numerous industrial plant applications.

(11) No recorders. Many combination models which include cyclometer counters.

17. Viscous Drag Tachometers

The principle employed in this class is the proportionality of the drag on a solid immersed in a whirling body of fluid, to the speed at which the fluid whirls. The fluids actually employed range from air to mercury. When a liquid is employed it naturally has to be contained in a suitable vessel and this often requires a vertical axis so that such instruments can only be used in one position. In liquid-filled devices designed to be used in any position, the pointer spindle must pass through a stuffing-box. The friction is enormously greater than that of an ordinary instrument-spindle pivot.

The driven members vary from cups, rings and disks to simple vanes. They are generally pivoted on jewel bearings, except in the case mentioned above; they carry the pointer and are restrained by suitable springs. Some are entirely immersed in the whirling fluid, others partly. The angular displacement caused by viscous drag is the measure of the speed but it seldom is linear. With air the viscous drag is approximately directly proportional to the speed of rotation but only up to a critical speed; with liquids the force varies between somewhat more than the first power and the second power—as nearly the square of the speed in the case of mercury, the second power being the theoretical limit. The relation is always empirical for any particular design, for any particular fluid and often for any particular instrument. Every instrument should be individually calibrated. For example, in the case of a certain model of a mercury-filled tachometer designed for

aircraft use (with a perforated disk driven by the shaft and a vane in close proximity to the disk, both completely immersed in the mercury) the scale opens out progressively, as the square of the speed or nearly so, but only up to a certain point, above which it closes in rather suddenly—suggesting that above this speed there occurs an increasing "skin" or surface slip effect.

Again, in the case of air vane tachometers employing two vanes in close proximity (one driven and one spring restrained and carrying the pointer) the torque varies as nearly the square of the speed—suggesting that the torque is not a true "viscous drag" in that particular design.

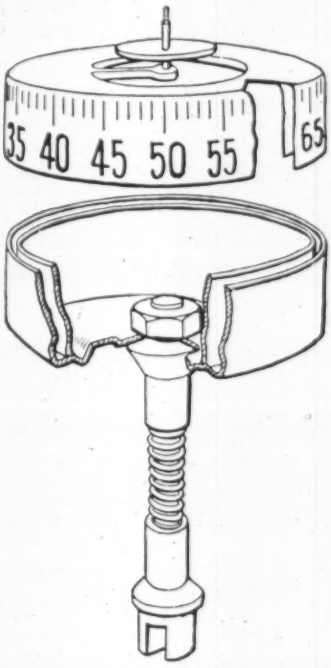


Fig. 559

In spite of many years of research on such instruments in many countries—the literature is quite voluminous—there are few commercial models suitable for industrial service. One reason is that the temperature coefficient is large in the case of liquids, and its equivalent—the atmospheric density coefficient—is likewise considerable in the case of air. It is true that the viscosity of a gas does not vary with pressure, but actually the accuracy of most of the air-drag instruments is seriously affected by changes in weather. Not one commercial model belonging to this class of tachometers is acceptable for engineering test work.

The principal parts of an instrument employing the air drag principle are shown in Fig. 559, taken from Diederichs & Andrae as well as the following description: This instrument consists of a pair of concentric cups fixed to a vertical shaft driven by the engine. Into these cups another pair of inverted concentric cups fits so as not to touch at any point. The space between the two pairs of cups is made very small and the second pair is made very light, usually of thin aluminum. The spindle on which the second pair of cups is fastened is mounted in jeweled bearings to reduce friction and the movement of the spindle is resisted by a fine spiral spring. As the lower cups are rotated they will tend to cause the upper cups to rotate also against the restraining action of the spring, due to the viscosity of the thin layer of air between the walls of the cups. This force is of course small and the instruments will not be accurate if not carefully made and handled.

Of the various forms of liquid-drag tachometers which have been investigated for the present discussion, none appears to be so suitable for industrial service that it merits preference over tachometers belonging to the other classes, for any reason whatever.

INSTRUMENTS BOOK SHELF

The books reviewed in this section can be supplied by the Instruments Publishing Company.

AVIGATION. *By Bradley Jones.* John Wiley & Sons, Inc. New York, 1931. Cloth 5 x 7½ inches, 314 pages. Price $2.75.

The use of the word "avigation" has led the author to a number of inconsistencies. The companion word is "avigator" which is used only three times compared to the general use of the word "navigator," throughout the book. Further, the terms "navigation" (page 40) and "air navigation" (page 42) are used in the same sense as avigations. This is merely further evidence that the coinage of the word avigation fills no real need.

The heart of this volume is contained in the three chapters outlining the astronomical methods of aerial navigation which take up about 125 pages. This subject is treated in a workmanlike and authoritative manner and is profusely illustrated by examples. No other volume has come to the reviewer's attention which so well or so completely summarizes the various methods of determining the line of position which are under general experimentation as alternative to the St. Hilaire method. An exception however should be taken to the statement that these shorter methods of computation are of relatively little benefit notwithstanding the author's well deserved reputation as an expert in this field. The chief stimulus in evolving the shorter methods is the unsuitability in many ways of those hitherto standard. One example bearing out this conclusion is given in the book itself. In the Hegenberger-Maitland flight to Hawaii the altitudes and azimuths of a number of celestial bodies were computed before the flight for three positions on the course in order to shorten the labor for the navigator. The author modestly fails to state that he originated the method and made these precomputations. Work on these alternative methods must continue until one is evolved which is best adapted for general use by the aircraft navigator.

The other chapters of the book do not measure up to those on astronomical methods. In the two chapters devoted to aircraft instruments only the treatment of the magnetic compass is at all adequate. In particular the description of sextants with artificial horizons and of drift meters and course computers should be amplified. Five chapters are given over to a brief discussion of maps and charts and to methods of dead reckoning. Brief chapters on meteorology, on radio navigation and fog flying are included. The latter two are far from being up-to-date or complete. Seven of the more prominent over-ocean flights made previous to 1927 are briefly described from the viewpoint of the navigation. It is rather surprising however that none of the flights of Admiral Byrd or Kingsford-Smith were included.

The figures on the whole are quite adequate. Line drawings are favored over photographs, which in the opinion of the reviewer, adds to the clearness. Strange to say there is almost no reference to other publications on the subject matter of the book.

A number of minor imperfections were noted. The designation of the ordinate of Figure 29 has been omitted. The latter half of the central paragraph on page 284 is ambiguous if not meaningless. "Mineral spirits" not "kerosene" is the damping liquid now used in magnetic compasses. Both are petroleum derivatives, but mineral spirits has about one-third the viscosity of kerosene. More serious, it is believed that the difficulty in mounting compasses so as to secure freedom from the effect of vibration is minimized. Further, none of the fore-and-aft inclinometers described is commonly used. It should be emphasized that the pitot-static air-speed meter is practically the only type now manufactured, the pitot-venturi type being obsolescent. In calibrating air-speed indicators the standard density is that of air at a temperature of 15°C not 16°C. It is stated under Fog-flying that "A pilot flying through fog will undoubtedly be looking over the side most of the time peering for openings, with frequent hasty glances at his instrument board." This is surely not generally the case.

Although the inclusion of problems for solution indicates that the book is designed for class room use, the subject matter and arrangement on the whole are such that it is better suited for reference use by pilots and engineers. The arrangement of the material could be greatly improved. In spite of these imperfections, which perhaps bulk too large in this review, the book is well worthwhile having for reference, containing as it does the essence of the author's rich experience in aircraft navigation while associated with the Engineering Division of the Army Air Corps.—W. G. Brombacher.

PRINCIPLES AND PROBLEMS OF AIRCRAFT ENGINES. *By Minor M. Farleigh.* John Wiley and Sons, Inc. New York, 1931. Cloth, 6x9¼ inches, 277 pages. *Price $3.00.*

The title of the book is somewhat misleading. It might have been more appropriately called: "Servicing and Maintenance of Aircraft Engines." It is mainly intended for the use of licensed aircraft engine mechanics and pilots, or those who plan to enter these professions, and want to be informed about what the practical side of these professions hold in store.

After an elementary theory of aircraft engines the author describes, each in a separate chapter, the various details entering into aircraft engine servicing and maintenance, such as: valve timing, firing orders, ignition timing, aircraft magnetos, carburetors, superchargers and lubrication. The language is free from technicalities, but it is clear and understandable. The thorough study of these chapters will help the serious student to acquire the necessary background for the intelligent understanding of the functioning of the engine.

Under the heading: Trouble Shooting, which is one of the most valuable chapters of the book, the author analyzes the procedure of finding troubles in aircraft engines and describes a number of unusually baffling cases, together with their solution.

The detailed description of the Pratt and Whitney Hornet engine, the Kinner K-5 engine and the Packard Diesel engine fills three chapters. These are also lucidly written, giving sufficient information on all points entering into their servicing and maintenance. A short chapter on the care, inspection, adjustment and balancing of propellers follows. A final chapter deals with the glossary of aircraft terms.

It is regretted that no space is devoted to instruments (i. e. stethoscopes, stroboscopes, etc.) used in maintenance work. Also, a description of the painstaking timing up and precautions to be used in the preparation for record-breaking attempts (long distance flights, duration flights with refueling, speed attempts, etc.) could probably have been included in the book with advantage to the reader.

The book can be thoroughly recommended especially to the ground personnel who are responsible for maintaining the modern aircraft powerplant in an efficient and dependable condition. It can be welcomed as a useful addition to the existing literature on aircraft engines.—Kalman J. DeJuhasz.

NEW INSTRUMENTS

Recently Developed by Instrument Manufacturers

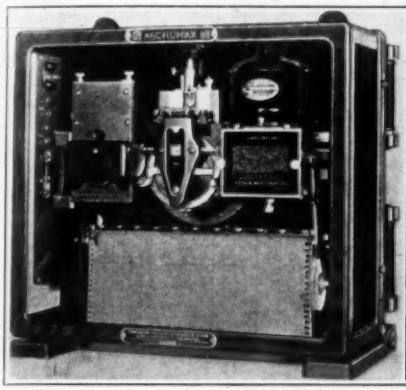
Write Information Section, Instruments Publishing Co., Pittsburgh, Pa., for additional information.

Improved L & N Potentiometer

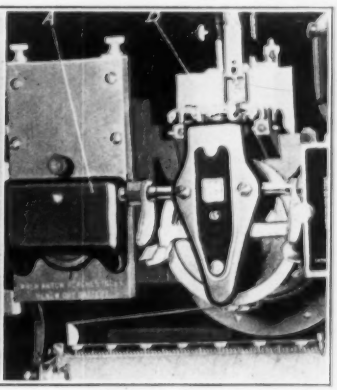
(Leeds and Northrup Company)

THE instrument has been given the name of "Micromax" to distinguish it from the preceding L & N Potentiometer Pyrometer which this company has built for industry since 1910.

The L & N Micromax pyrometer is claimed to be more sensitive, more rugged, and faster in operation. It is fully automatic and eliminates daily attention and adjustments. These advantages are obtained by the new mechanical balancing device, shown in the accompanying photograph, and the automatic standardizer, also shown, which checks the instrument circuit every 45 minutes or less. L & N recorders now in operation may be equipped with Micromax improvements.



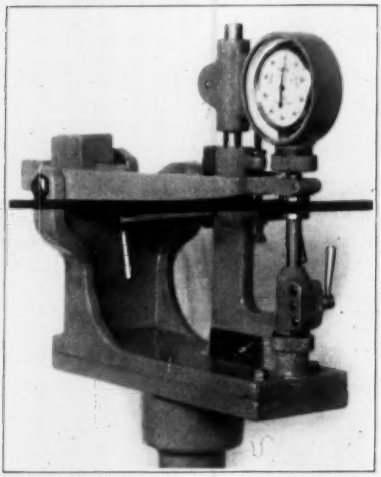
Micromax, the Improved L & N Potentiometer Pyrometer



Closeup of the automatic standardizer (A) and the more sensitive, quicker-stepping balancer (B). The self-standardizer operates automatically every 45 minutes or less.

The Micromax balancing device is claimed to give micrometer sensitivity, needs no adjustments and is remarkably fast-acting. Due to the complete elimination of operating clearance between galvanometer pointer and levers, pointer deflections as small as 1/1000th of an inch can be detected and recorded. Because of this ability of the balancing device to detect extremely small pointer movements, Micromax gives greater sensitivity with greater ruggedness. The recording pen can step across the entire 9¾" of calibrated chart in less than 22 seconds, the size of each step being far more closely related to the extent of pointer deflection. The non-slip driving clutch for the pen is direct and simple, and is automatically prevented from attempting to move the pen beyond either end of the scale.

The automatic standardizer is a simple device which automatically checks the potentiometer circuit every 45 minutes or less, giving a much closer adjustment than is obtained by hand. Also, the circuit can be standardized at will (as after changing a thermocouple, when a check is desired) before the 45-minute cycle is completed. By means of the automatic standardizing, the machine itself assures potentiometer accuracy, and the memory of an operator need not be depended upon.



New Wire Gage

(Federal Products Corp.)

THE illustration shows the new Federal wire gage having a range of 0.2 inch graduated in thousandths of an inch. The indicator is enclosed in a dust proof auxiliary housing and the interchangeable anvils for any specified sizes can be furnished.

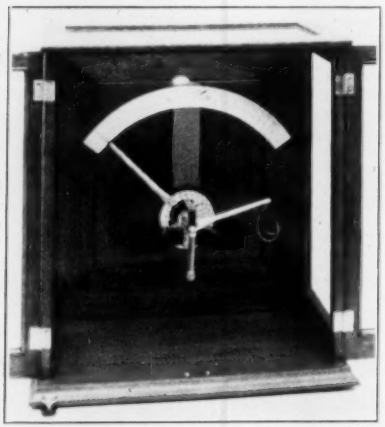
The gage is furnished with an adjusting screw for instantly setting to any desired size. A safety rocker arm is attached for holding anvils out of contact, and a compensating weight to adjust for proper tension is furnished. Guide rollers can be furnished.

Light Capacity Direct Reading Scale

With Special Oscillation Damper

(Amthor Testing Instrument Co. Inc.)

THIS model operates on the simple gravity principle, all readings being automatically pointed out on a graduated quadrant. This new model is equipped with a special damping device which brings the indicator arm to rest at the correct reading almost immediately after the specimen is placed in the pan. There is no manipulation or balancing of weights required, no calculation or clerical work with its corresponding loss of time. Although the damping device cuts down the former oscillation of the indicator arm, it does not affect the scale's accuracy or sensitivity.



With the new damping device, this scale combines greater speed of weighing with accuracy and simplicity of operation. For this reason it is particularly practical for use in production weighing of fine specimens. In addition to its use in weight determination the scale can be calibrated in practically any standard industrial graduation such as is used for testing foil, paper, etc. For foil, the quadrant is graduated to show the yield in square inches per pound. For paper, it can be graduated to show the moisture content, or to show the ream weights of the full sheet when only a small portion of the sheet is used for test. Practically any special graduations, and auxiliary rows of graduations on the same quadrant can be had to order, and in either Metric or English System.

The quadrant has a radius of 7" and is finished in a baked dulled white enamel against which the black graduations and figures stand out in contrast, presenting a clear and distinct reading easily visible even from a distance. The entire scale is enclosed in a mahogany and glass case.

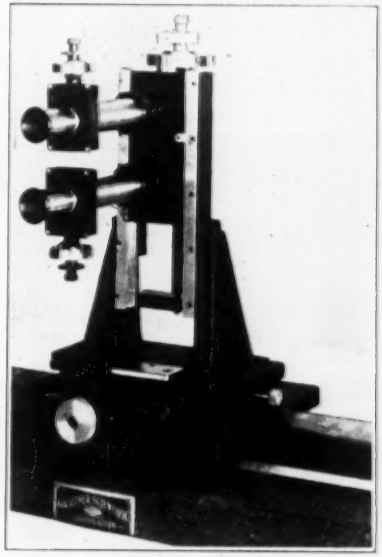
The scale contains no mechanical devices of any sort which might affect the accuracy of the readings, or cause it to become out of calibration. Although extremely sensitive it is very strongly constructed and will withstand hard, continuous service over a period of many years without getting out of order.

It is primarily designed for applications requiring speed of operation, with accuracy and simplicity and is not intended to replace the analytical scale for minute testing operations.

Special Double Micrometer Microscope Measuring Instrument

(Gaertner Scientific Corp.)

THE instrument is mounted on a heavy cast-iron base about 8" wide, 33" long and 2" high. The base is heavily ribbed, arranged to be supported on 3 points. The top of the base is machined and has suitable guides for the top carriage on which is mounted a cross slide with a vertical micrometer slide holding the 2 microscopes. The first slide is about 8" long and 8" wide, made of cast-iron and of sufficient weight to keep its position without clamping. The cross slide is fitted with a cross screw focusing motion of about 1" range. On top of this slide is mounted a micrometer slide which is fitted with a carriage made of Invar and which supports 2 micrometer microscopes at a distance of $2\frac{1}{8}$" apart. The micrometer slide is fitted with a screw of .05" pitch. It has a range of about $2\frac{1}{2}$" and the micrometer head reads to .0001". The microscopes are fitted with objectives of about 60 mm. E.F., which will give a working distance of about 90 mm. ($3\frac{5}{8}$") with a tube length of 180 mm. (7"). The microscopes will have a magnification of 2 diameters and are fitted with Filar micrometers. The tube length is so adjusted that one division on the micrometer drum is equal to .0001". The total range of the Filar micrometer (measured on the object) is about .2". The microscopes are provided with illuminating devices built inside the tube, consisting of a small total reflecting prism and miniature incandescent lamp.



The highest position of the upper microscope is 10" above the lower surface of the base.

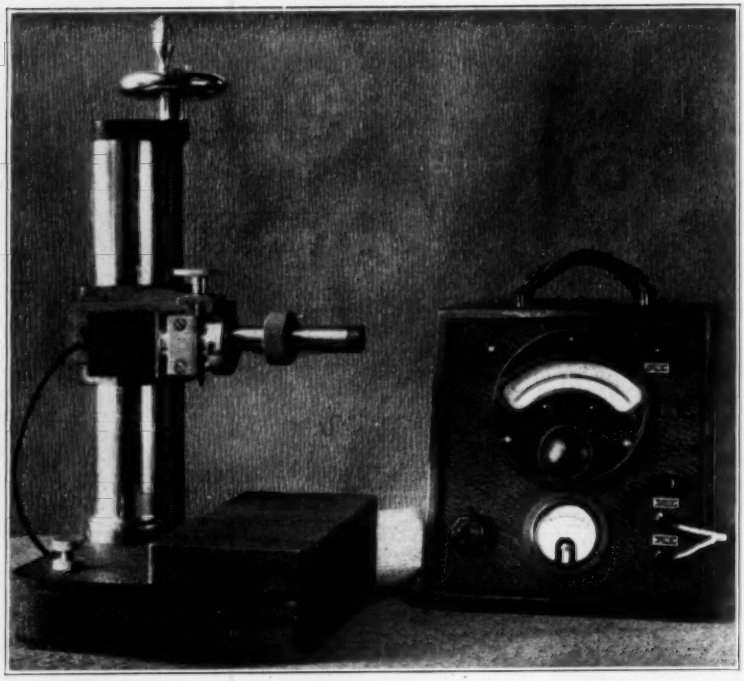
The Electrolimit Gage

(Pratt & Whitney Company)

THE Electrolimit Gage is an extremely sensitive and accurate comparator, suitable for checking work within very close limits, and is applicable to quantity production owing to its rapidity and simplicity. Previously its use was confined almost exclusively to the laboratory. Under the new arrangement its greatly superior inspection advantages will be brought within the scope of general shop use. It now can be produced economically enough to enable it to replace many present mechanical gaging operations.

The Electrolimit Gage consists essentially of a small gaging head which carries a pointer to contact with the work. The movement of this pointer changes the balance of the electric circuit, so that errors from true size are indicated by a needle traveling over the scale of an indicating instrument. Electrical magnification from 500 to 10,000 is possible, so that the gage can be used for a wide range of limits. (Length of scale 5").

Its application in production lines have made savings that have offset its increased cost many times over. In addition several manufacturers are using the Electrolimit gage to select machined materials into groups on a 1/10,000 basis for both inside and outside diameter, allowing them to assemble parts on a 1/10,000 basis. This eliminates the necessity of handling materials several times for hand fitting.



A standard gaging head to be used in conjunction with the General Electric indicating electrical devices is planned. Standardized brackets and fittings will be available for mounting the gaging head for various types of work, so that in the near future the Electrolimit Gage will be standardized for a great many different production applications.

The use of the Electrolimit Gage is very simple. It is available for either external or internal work. It can be set very quickly to extreme accuracy, after which the operation of gaging does not need to be performed by skilled toolmakers. No sense of "feel" is required, as the gaging is done entirely by the variation of an electrical circuit which is transmitted to the pointer in the instrument. The position of the pointer either inside or outside of two limit marks indicates whether the piece will or will not pass inspection.

When being used for external work, Hoke Precision Gage Blocks are used to set the upper and lower limits desired. First the low limit is set up with the proper stack of blocks, and with the latter in position under the diamond contact a simple adjustment is made with a small wrench to bring the pointer to the desired position on the scale. Then the high limit is made up on a second stack of blocks and placed under the diamond contact, and the second position of the pointer noted. From then on pieces of work brought under the diamond contact must allow the needle to remain between the two marks on the dial if the work is to pass inspection.

For internal work two master solid ring gages representing the "go" and "not go" dimensions are needed to set the gage. These rings are slipped in turn over the gage spindle and rotated once. Again the two positions of the needle are noted, one for each ring, and work being inspected must permit the needle to fall within the two marks as before. This method entirely eliminates "feel" which is so necessary to present mechanical gaging of internal work.

Palo Company, which has devoted its efforts exclusively to a specialized field of laboratory apparatus for many years, has united with Teschner Myers Co., Inc., which has handled general laboratory supplies. The combined business will henceforth be carried on with larger quarters at 81 Reade Street, New York under the name of Palo-Myers Inc.

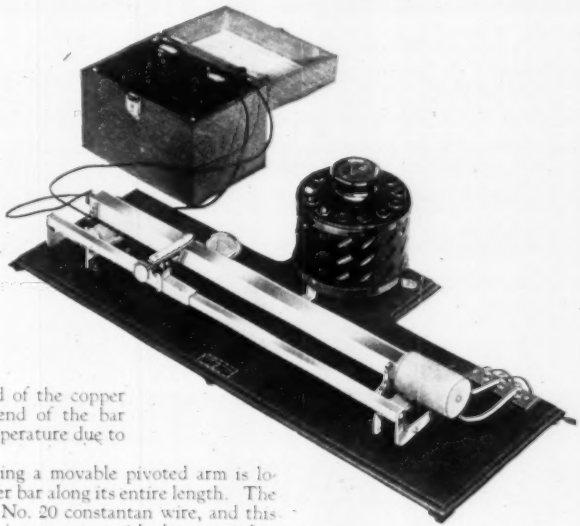
Dennis Melting Point Apparatus

(Burgess-Parr Company)

A SURVEY of the methods and devices for determining the melting points of organic compounds indicates the lack of any rapid, accurate method. The Dennis Apparatus provides a method that is equal in accuracy to any previous method, and the time required for a determination is only a matter of seconds.

The principle involved in this apparatus is the melting of the organic compound on a pure copper bar, and the measurement of the temperature of the bar by a copper-constantan thermocouple. The reading in °C is indicated directly by a potentiometer.

The apparatus consists of a copper bar 25 mm. x 25 mm. x 61 cm. long, mounted on an aluminum base 75 cm. long and 33 cm. wide at the widest point. A replaceable element containing nichrome ribbon is located over a length of 7½ cm. of one end of the bar. A rheostat and ammeter are provided to permit any desired regulation of the temperature of the bar. By proper setting of the rheostat, any temperature may be maintained at the hot end of the copper bar. The opposite end of the bar will be at a lower temperature due to radiation.



A guide rod carrying a movable pivoted arm is located beside the copper bar along its entire length. The movable arm holds a No. 20 constantan wire, and this wire may be brought into contact with the copper bar by a simple adjustment. The constantan wire and a copper connection from the copper bar are connected directly to the potentiometer, where a reading may be obtained directly in °C. The particular instrument recommended is Leeds & Northrup No. 8658-X with a range of room temperature to 300°C.

The procedure involves bringing the copper bar to the approximate temperature by referring to the direction booklet for the current required. Fine particles of the substance are dropped along the surface of the bar from a spatula. There will be a distinct line of division between the particles in the molten and solid state. The point of the constantan wire is brought down exactly on this line by adjusting the movable arm.

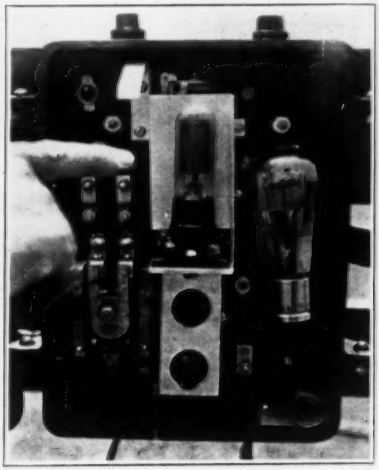
Experiments have shown that exactly the same melting point is obtained regardless of the temperature of the hot end of the bar.

This apparatus is particularly useful for substances which decompose readily on heating Due to the time required in approaching the melting point by the "capillary tube" method, the apparent melting point may vary between wide limits, depending upon the rate of heating

Outdoor Lighting Control Relay

A TINY electric "eye" that never sleeps keeps vigil 24 hours each day for changes in natural light. The "eye", a photo-electric tube which controls 9 street lighting circuits in Albany, N. Y., is located on the roof of the Albany service building of the New York Power and Light Corporation. This recently-developed street lighting control unit one of the first to be installed for regular use, is a product of the General Electric Company'

As soon as a certain degree of darkness prevails, regardless of the hour, the photo-electric tube operates a relay, which, in turn, supplies power to throw a switch turning on the street lights. During the period of darkness, contact is maintained and the lights remain on, but as soon as daylight reappears, the contact is broken and the switch opens, turning off the lights.



The light-sensitive "eye" of the photo-electric tube is pointed to the north so that it "sees" the average light and thus avoids direct sunlight. As small a change as one millionth of an ampere will operate the mechanism. The power consumed in one hour by the street lights on the 9 circuits is nearly equal to the average consumption of a residential customer in Albany for 3 months. In other words, a millionth of an ampere controls about 140 kilowatts of electric energy.

A very small amount of current flows through the photo-electric tube, the current varying with the amount of light striking the light-sensitive electrode—(the more light, the greater the flow of electricity through the tube). This small amount of current is amplified by means of a vacuum tube to a degree sufficient to operate the relay. Thermal time-delay relays are included in the equipment to prevent instantaneous operation in response to disturbances such as the passage of a cloud over the sun, a flash of lightning at night, a person walking in front of the unit, etc., but once the contactor has been actuated, it will remain and not "flutter" at the critical light intensity.

At present, only 9 of the 75 street lighting circuits in Albany, (the 9 circuits containing about 400 incandescent street lamps), are controlled by this photo-electric tube. Ultimately all the street lighting circuits in the city will be operated by similar equipments which will be located in various sections of the city. Similar installations are planned to make this automatic system operative in other cities and districts served by the New York Power & Light Corporation.

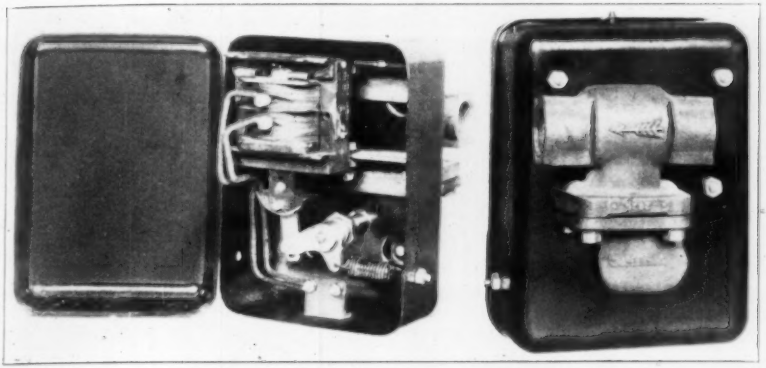
It is claimed the photo-electric tube is more flexible and positive in operation than time switches or manual operation. For example, during the 97% total eclipse of the sun in 1932, when the Albany area will be darkened, the streets lights will probably turn on:—or ,on very dark stormy days, which are common, the lights will turn on automatically. Changes of the seasons will not affect the new system, for the only factors which govern this controller, and the only ones which are important, are light and darkness.

New Solenoid-Operated Valve

A NEW solenoid-operated valve, for controlling liquids and gases under pressure has been announced by the General Electric Company. Some of the many uses for which the new valve is designed are: for operating steam or air whistles, for controlling the flow of brine through cooling pipes in cold-storage rooms, for remotely or automatically controlling the supply of oil or gas to furnaces, for automatically controlling the flow of liquids in connection with weighing machines, and for controlling the flow of water in cooling jackets on compressors.

The valve body is made of high-grade castings in 2 sections with the upper section fastened to the lower by bolts. The threads for the pipe connection are standard pipe threads. An arrow on the upper body casting indicates the direction of flow.

The gland connected to the operating mechanism is of the rotary type which reduces the friction load. The seat and poppet are carefully ground to fit and only high-grade materials, suitable for liquid or gas that is to be controlled, are used. The material is distributed so that a wide seat is obtained, giving long life and reliable operation. The valves can be made normally open or normally closed, in the field, by drilling the mounting holes in the case and

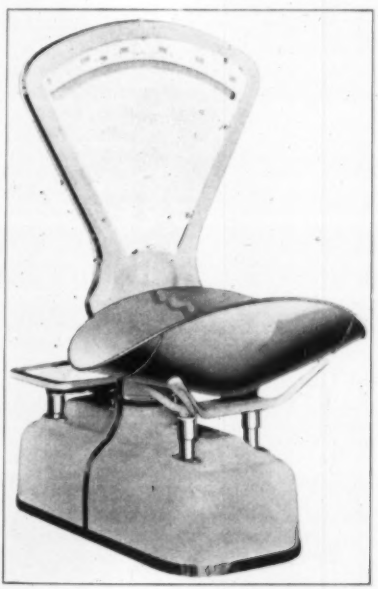


transferring the solenoid and operating mechanisms to the opposite side. The valves are of the unbalanced type and require little power for operation. A standard solenoid is used. All of the coils are designed for continuous duty and the solenoids are selected so that there is ample power for operation. The operating mechanism is so arranged that the solenoid plunger is permitted to accelerate without load for a fraction of the stroke, thereby effecting quick, reliable operation.

A sheet-metal case with a hinged cover encloses the solenoid and operating mechanism. Suitable knockouts are provided in the case for conduit connection.

The following are a number of the advantages claimed for this device:

1. Operating coils are designed for continuous duty.
2. Valves are of the unbalanced type and require little power for operation.
3. Valve seats can be ground without removing the valve from the line.
4. Rotary-gland design results in much less wear and friction than are usual with the reciprocating type.
5. Solenoids have more power than is required to operate the valves. The operating mechanism is so designed that the solenoid plunger accelerates without load for a fraction of the stroke, thus effecting quick and reliable operation.
6. Minimum number of wearing parts.
7. Valve seats are wide and designed to provide long life and dependable operation.
8. Solenoids and operating mechanisms are supported from the main section of the valve-body castings. This sturdy construction removes all strains from the valve seat and operating members.
9. Solenoids and operating mechanisms are enclosed in sheet-metal cases with knockouts suitable for conduit connection.



New Laboratory Scale

(Toledo Scale Company)

THE chart on this scale has a capacity of 500 grams, with a mark and figure for each gram. It also shows the avoirdupois equivalents. Additional capacity up to 5 kilograms may be secured by the use of weights.

This scale is so designed that the oscillation ordinarily found in extended beam type scales is eliminated.

The chart housing may be set at any convenient angle, and the scale comes equipped with either a pan, platter or scoop as the purchaser desires. It is finished in gray baked enamel, which is easily kept free from dust and dirt.

This scale is for use, primarily, in industrial research laboratories. It will be a great aid to research engineers as it enables them to weigh ingredients accurately, to the gram, in approximately one quarter the time consumed with balance equipment.

New Sheet Metal Tester

(*Detroit Testing Machine Co.*)

MANY new and novel features are incorporated in this new sheet metal tester. Instead of the conventional method of holding down the material to be tested by means of a hollow screw, clamping on this machine is done hydraulically from below. It is claimed that by former methods the load, when applied, had a tendency to force the grips apart, thus permitting the metal to draw under, and that it involved considerable labor to clamp sufficiently tight to avoid this. The hydraulic device clamps from below, overcoming this tendency; the clamping pressure is always in proportion to the load applied and involves no physical labor. The greater the load the harder it grips. All clamping devices being removed from the top of the machine, the operator has an excellent view of the test while it is being made.

The large 12″ manometer permits large graduations and correspondingly fine readings. A maximum pressure hand is provided to record the load until the reading is taken by the operator.

Oil is used as the pressure medium and pressure is applied by a motor-driven pump of the gear type. Pump gears are hardened and ground and gear shafts run in ball-bearings. The motor also is ball-bearing mounted insuring long life and freedom from bearing trouble. Belts and chains have been replaced by a direct gear reduction drive. This drive is installed within the casing which acts as the reservoir and prevents the possibility of leakage frequently encouraged with outside mountings.

Safety devices guard against overloading and overtravel. Grips are of the circular type, hardened and ground and may be removed without tools if necessary.

For those requiring extreme accuracy on light material and large capacity combined in one machine a special arrangement is available. This consists of mounting two manometers on a heavy machine. One graduated from 0 to 5,000 or 10,000 lbs. depending on the nature of the work, and the other graduated up to the load capacity of the machine.

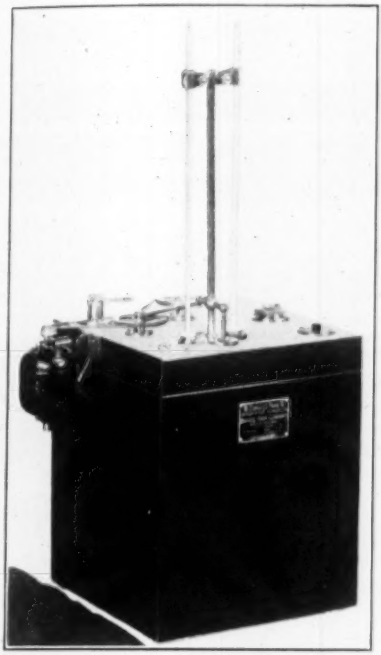
When making a test all operations are controlled by one graduated dial or knob. Turning this knob a half revolution to the right clamps the specimen and starts the test. The speed of the test ram is regulated by moving the dial back until the desired speed is obtained. When the test is completed another slight movement to the left gives a neutral position and the reading is taken. The knob is then given a quarter turn to extreme left releasing the work and returning the plungers to their original at-rest positions.

Two standard sizes are available, Models G-1 and G-2 with load capacities of 10,000 and 20,000 lbs. respectively.

New Adiabatic Calorimeter

(*Burgess-Parr Co.*)

A NEW model of the well established Burgess-Parr adiabatic calorimeter has recently been announced. By employing the method developed by Dr. S. W. Parr, complete adiabatic conditions are easily maintained throughout a run, this eliminating the time requred for determining radiation correction factors, and providing more readily obtained results by eliminating much computation. Radiation is prevented by maintaining the jacket temperature at all times equal to the calorimeter temperature, using manually controlled streams of hot and cold water for this purpose. In this way water of the proper temperature is introduced



into the jacket and is circulated on all sides, top, and bottom, so that radiation from the calorimeter cannot occur.

In addition, the instrument is provided with two matched and certified thermometers, a motor mounted on the jacket to provide power for stirring the calorimeter and for circulating the water in the jacket, an ignition system which is connected directly to a 110-volt source, and a pilot light to indicate the duration of ignition.

The calorimeter is provided with the time tested Illium bomb, which has become definitely established as a standard for calorimetric determinations.

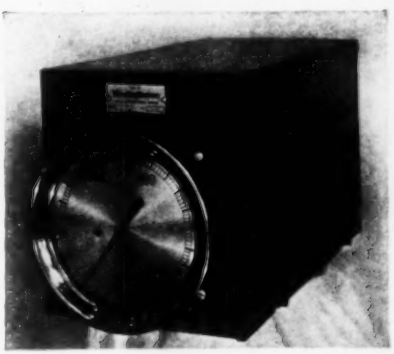
In addition to the calorimeter's use for fuel analysis, it finds applications in the chemical research laboratory, in which instance the complete adiabatic conditions provided by the jacket are particularly necessary.

New features of the improved design are, first, a novel screw type pump which maintains an efficient circulation of water in the jacket surrounding the calorimeter on all four sides, top and bottom; second, the installation of the motor on the jacket for circulating both the jacket water and the calorimeter water; and, third, the inclusion of a switch and pilot lamp for the ignition circuit, eliminating the need for external resistances. As an accessory, a new type of electrical water heater with close thermostatic control is available for use where hot water of uniform temperature is not available.

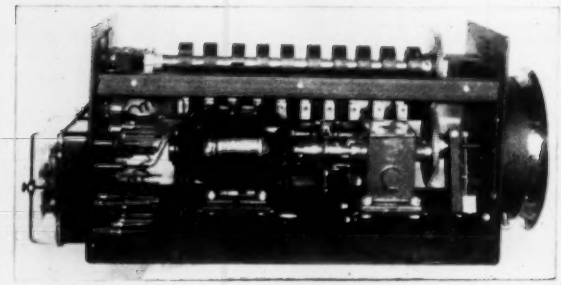
Multi-Contact Making Pressure Gages

A MULTI-CONTACT making pressure gage has been developed by the Westinghouse Electric and Manufacturing Company for use with supervisory control systems to indicate certain pressure readings at a remote point. It was developed for use with a pipe line pumping station to give remote indications of intake and discharge pressures.

Ten adjustable contacts are placed at predetermined intervals over the scale of the pressure gage. When the pressure changes sufficiently to make a new contact, a code of impulses is sent over the supervisory control wires to indicate the change to the dispatcher. Thus all changes are automatically sent through without the use of extra live wires. In general, the device consists of motor driven contacts which are made to follow the pressure gage. To accomplish this, the shaft of the pressure gage is extended through to the rear and a contact mounted on it which will follow the change in pressure. As the pressure tends to change up or down, it strikes another contact which is connected directly to a motor-driven shaft which is connected directly to a motor-driven shaft which rotates it in a direction to cause the contact to again open. Thus the motor-driven contacts will move or rotate in response to variations in pressure as indicated by the pressure gage.



Multi Contact Pressure Gage



Multi contact pressure gage with cover removed showing drive; following contact cam and cam assembly for sending signals.

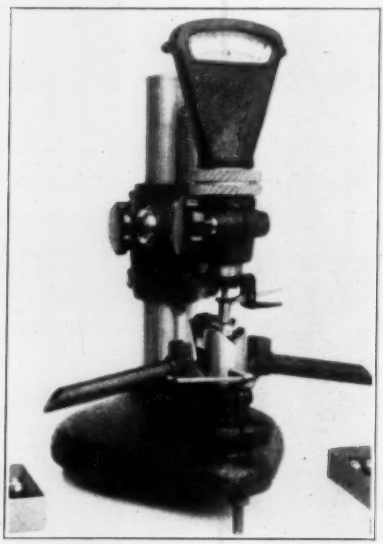
The contact carried along with the pointer has no mechanical connection to the rest of the device. The indicating contacts have a capacity of 5 amperes at 125 volts. The case is made practically dust proof and made for table or similar mounting. The device is usually made for storage battery operation so that readingsof pressure will be accurate even though the ac. supply to the pumps is interrupted.

Special Comparator for Checking Steel Balls

(R. Y. Ferner Co.)

THE illustration shows a micro-indicator stand designed especially for checking the diameter and roundness of steel balls.

In this use of the stand a small pin is inserted under the front edge of the base to hold the stand in a slightly tilted position and a vee block is used as a lower table of the apparatus. The balls to be tested are allowed to roll down this vee groove to an adjustable stop. The micro-indicator of fan-shaped type, which is used for these measurements, is provided with a lifting clip by which the contact plunger can be raised to allow the ball to take its proper position. The plunger can then be lowered for the measurement. The micro-indicator is provided with adjustable tolerance marks which can be set at any point over a range of .003" either side of the center.



When it is seen, by the reading of the micro-indicator, whether the ball in position is within or without the tolerance, a lever can be thrown to the right or left to eject the ball to one or the other of 2 tubular troughs leading to receptacles for accepted and rejected balls. Since the balls are thrown out at the rear of the vee groove it is possible to carry on inspection of the balls very rapidly, practically as fast as they can be fed in at the front of the apparatus. The micro-indicators used for this work have a knife-edge multiplication system of high accuracy and can be obtained graduated to as fine a reading as one twenty thousandth of an inch per division.

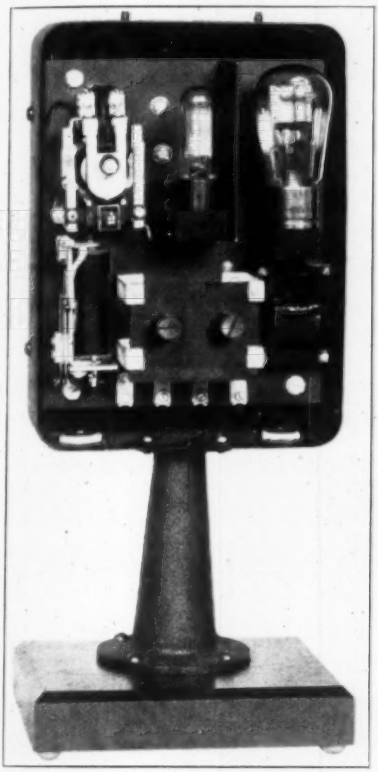
The stand has capacity for balls between $\frac{1}{8}$" and $\frac{5}{8}$" in diameter.

Indoor Lighting Control Relay

(General Electric Company)

PHOTOELECTRIC and pliotron tubes are used. The auxiliary equipment includes 2 potentiometers which can be adjusted from the front of the enclosing case, a sensitive relay, and a normally open contactor with 2 insulated, single-pole interlocks. There are also included the necessary transformer, resistors, etc.

One of the potentiometers, marked "intensity," is for adjusting the equipment to turn on the artificial illumination at a predetermined intensity of light within the room or building. The other potentiometer, marked "compensati g" is for adjusting the equipment to compensate for the additional illumination which will fall on the photoelectric tube when the artificial lights are turned on.



Operation is as follows: If the potentiometers are set at the proper position then, when the room or building light intensity decreases to that corresponding to the setting of the "in ensity" potentiometer, the equipment will operate to turn on the artificial light. This operation de-energizes the sensitive relay, which in turn, energizes the coil of the contactor, closing it. At the same time, a section of a resistor is short circuited by one of the interlocks, causing a change in the sensitivity of the relay unit. The amount of resistance short circuited is controlled by the adjustment of the "compensating" potentiometer. This change in sensitivity compensates for the increased light caused by the turning on of the artificial illumination and thus prevents the relay from operating to turn off the lights. The other interlock holds the contactor closed.

To turn the artificial lights off, the outside daylight must increase the total illumination in the room to a predetermined point which is above the light intensity when only artificial light is available. The equipment will then operate again, picking up the sensitive relay which, in turn short circuits the coil of the contactor through a resistor, thus allowing the contactor to open and turn off the light. At the same time, the original sensitivity of the unit is restored. This is accomplished by inserting the small part of the "compensating" potentiometer that was short circuited by one of the interlocks on the contactor when it was energized. The equipment is now ready to operate again by a decrease in the intensity of illumination in the room or building.

The CR7505-D3 relay can be supplied to operate from 110- or 220-volts at 25- or 60-cycles. The contactor is rated 15 amperes at 110- or 220-volts, a-c.

The equipment is designed for operation in temperatures not to exceed 150° F. The relay will draw about 10 watts or less when the contactor is open, and approximately 20 watts when it is closed.

The C. J. Tagliabue Manufacturing Company of Brooklyn, New York, has recently announced the promotion of A. F. Rucks to the position of General Sales Manager.

Mr. Rucks has been connected with the Tagliabue Co. for 18 years and for the past four years has served as assistant to Mr. L. C. Irwin, Vice President of the Company.

Mr. Rucks has gained notable experience in practically every phase of the Tagliabue Company's business and his success in full charge of sales may be readily anticipated.

New Fuel-and-Air Ratio Meter

(*Bailey Meter Company*)

THE primary purpose of the Bailey ratio meter is to provide furnace operators with an easily understandable guide which will enable them to maintain a definite relation between the amounts of air and fuel supplied to the furnace so as to obtain high combustion efficiency. This is accomplished by an ingenious method. Referring to the illustration it will be noted that the meter contains two recording pens. One records the rate of oil flow and is actuated by a simple mechanical type of mechanism which receives its motive power from the differential pressure produced by an orifice in the fuel line. In similar manner, the shorter pen records the flow of air to the furnace. At the time the meter is being installed, a complete combustion test is run on the furnace to determine what ratio between air flow and fuel flow corresponds to best combustion conditions, and the air flow mechanism is then adjusted so that this ratio is always obtained when the two records coincide, one upon the other. The furnace operator, therefore, merely has to keep the two pens together by proper manipulation of the air supply to be assured that maximum economy is being secured.

Should the air flow pen be above the fuel flow pen, it is an indication that too much air is being supplied with a consequent increase of stack losses. Conversely, should the air flow pen be below the oil flow pen, it is an indication that too little air is being supplied with consequent loss due to unburned fuel.

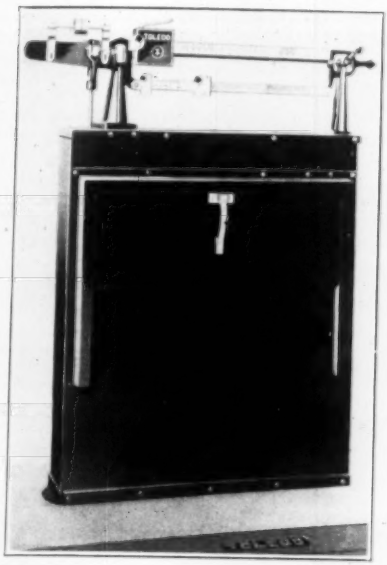
In addition to serving as a combustion guide, the ratio meter is valuable as a fluid meter on the fuel line. It records and indicates the rate of flow in any convenient terms, and the total flow may be given by the four dial integrator which may or may not be installed in the meter as desired. Thus the meter furnishes daily graphic pictures of furnace operation and supplies data for cost accounting systems.

The ratio meter has been so designed that it is possible to install auxiliary recorders of temperature or pressure when advantageous, to give records of these factors on the same chart with the flow records. This feature makes comparison of related factors a simple task, especially since the 12″ diameter charts are uniformly graduated and are marked with direct reading scales. Each factor is recorded in an individual color so that it can be easily distinguished from other records.

Convert-O-Matic Scale

(*Toledo Scale Company*)

A NEW and entirely different type of beam scale embodying features of accuracy in design and construction heretofore found only in automatic scales, offers new and outstanding features of weight control. It has a full floating platform which stops losses caused by the inevitable wear resulting from movement of the knife edge pivots on the bearings. It is possible, at any time, to put on the automatic indicating dial with its full floating double pendu-



lum mechanism which has no pivots or bearings. Should requirements demand an automatic scale of greater capacity, a further adaptation of the Convert-O-Matic is possible. Its total weighing capacity may be increased one to four times merely by adding unit weights in the same cabinet.

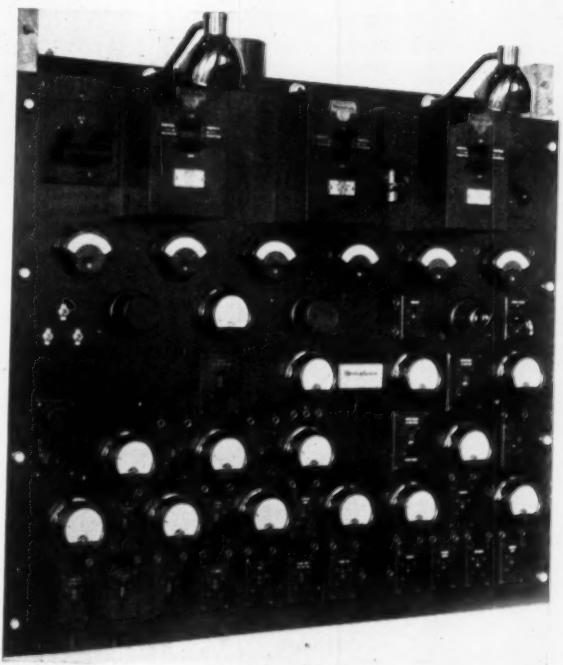
This scale is one which does not have to be scrapped when weighing equipment is modernized, because all cabinet, lever and platform features as originally installed are of sufficient strength, durability and accuracy to be used with the much more accurate dial indicating mechanism.

Features of the Convert-O-Matic are: Pivots may be changed without honing or grinding. Heretofore, pivot changing was an expensive, tedious job, calling for the skill of a trained scale mechanic for a day or more. Now this can be done in an hour or two.

A few pivots may be kept on hand for an emergency as they are interchangeable. This saves costly service work and stops delays in weighing operations.

Longer pivots reduce the pressure on the knife edges to one-fourth of that permitted by official engineering specifications. Less pressure on knife edges means less wear and finer accuracy.

Three sides of the cabinet are of one piece of pressed steel. This gives unusual strength and stability.

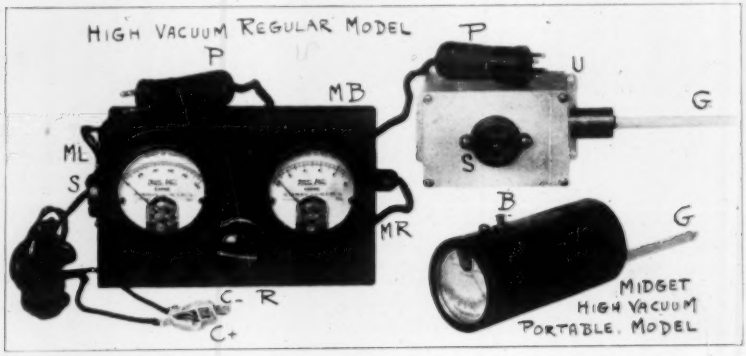


This small switchboard controls all light and power circuits, generators, motors, circuits to engine rooms, radio room, control room, fire control, lights and other operating equipment throughout the great dirigible ZRS-4 "The Akron." The three circuit breakers across the upper portion of the board are of special importance. The board and all electrical equipment on the dirigible were furnished by the Westinghouse Electric and Manufacturing Company, most of the items being of highly specialized design.

Tru-Vac Gage

(*Continental Electric Co.*)

UNLIKE the mercury gages the TRU-VAC gage indicates, at all times, the exact degree of vacuum in the system to which it is connected. It is electrical in operation and has nothing to wear out. The indicating mechanism can be installed at any point, either at the machine with the gage unit, or at any other point desired. Wires are used to connect the gage unit proper with the indicating mechanism. If it is desired a recording device may be connected with the instrument and a continuous record of vacuum kept. The meter cases can be tapped back of the left hand meter and a telephone jack can be inserted to facilitate connecting such recording devices. This is desirable when running special tests, as each group of specials can be indicated on the record and the vacuum conditions definitely known for each test. Or in the case of production, it is easy to check back and find the exact vacuum conditions at the time the tubes were exhausted.



The variable voltage which actuates the left meter ML is impressed on the contacts where standard phone plugs may be inserted and the wires may connect with a recording potentiometer for drawing a continuous vacuum curve or to a relay system for lighting red, green, and yellow lights over the machine depending upon the degree of vacuum, or to shut off a port with a magnetic switch. If a no load vacuum tube voltmeter relay is connected, it will not change the calibration of the meter although this is unnecessary as the exact calibration is generally unimportant.

The TRU-VAC gage indicates vacuum conditions instantaneously and continuously. It indicates the speed of pumps and evacuation of systems as well as the degree of evacuation. It shows no discrimination between gases as does the mercury gage and reads water vapor as well as dry air pressure. It is this moisture indication that makes it a necessity in tube and lamp work, or where the real conditions must be known.

In the case of such devices as sun lamps, mercury arc rectifiers, certain neon and gas-filled tubes, photo cells and power tubes, small traces of moisture cause sputtering of the electrodes and other trouble, and a gage of this nature is almost a necessity in order to cut "shrinkage" and lengthen life to a practical value.

DIRECTIONS FOR INSTALLING TRU-VAC GAGE

Connect glass tube "G" of gage unit box "U" to part of exhaust system where reading is desired. Either seal on glass or connect in rubber.

Connect battery clip "C+" to positive terminal of 4 volt storage battery (or dry cell as drain is about 80 milliamperes) and "C—" to negative terminal.

Connect meter box "MB" with unit box "U" by inserting cord plugs "P" in sockets "S."

Set pointer of right hand meter "MR" at red line on dial (80 mils), by means of rheostat "R." Left hand meter "ML" will now indicate the degree of vacuum in unit box "U," which may be interpreted in microns, when desired, from curve.

Unit box "U" should be grounded as a special feature is a grounded grid preventing spark coils from disturbing the meter reading.

To install midget, insert tube "G" in rubber, press button "B," read approximate microns from dial.

Automatic Viscosimeter

J. Kuttner

THE viscosity of engine lubricating oils, though varying considerably from one brand of oil to another, and subject to further fluctuations throughout the service life of the oils, has not, until recently, been subject to anything like adequate control from the users of engines notwithstanding the critical importance of viscosity from the viewpoint of successful engine operation. The Saybolt test for viscosity requires a laboratory procedure.

The commercial marketing of an automatic viscosimeter by the Viscosity Engineering Corporation is arousing particular interest, especially because the new instrument gives indications capable of being read on a dial by anyone and because its principle of operation is such as to give results approximating the true physical viscosity.

The instrument consists essentially of an ordinary pressure gage measuring the head set up by oil flowing through a friction tube at a rate held constant by a diaphragm and ball check arranged somewhat as in an ordinary reducing valve. As will be noted from Fig. 1, the seating of the ball valve is controlled by a point on the diaphragm button while oil can flow between the ball and its seat into the space above the diaphragm. The latter has a small calibrated hole through which oil can get underneath the diaphragm and from there to the calibrated outlet tube at the left. The space between the diaphragm and the outlet is connected to the pressure gage, whose readings measure the true viscosity with a degree of precision considerably higher than that called for by practical conditions.

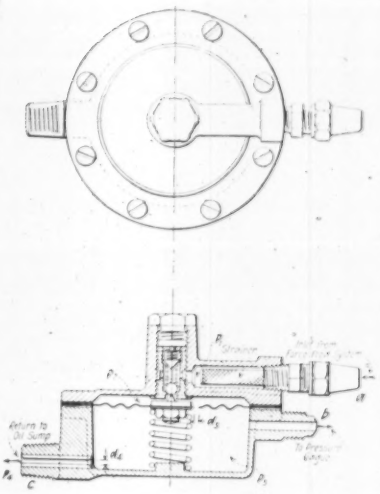


Fig. 1

The instrument has three connections, *a*, the inlet, *c*, the outlet, and *b*, the connection to the pressure gage calibrated to read in viscosity units. According to Fig. 2 it will be seen that the inlet can be connected by piping or tubing to any convenient point on the discharge line from the force-feed circulating pump, while the oil returning from the instrument can be led to any suitable point in the engine crankcase or oil drain. Although the instrument is provided with a standard pipe plug at *c* to permit of its being tapped directly into the crankcase, almost any other convenient location may be selected, while the position of the gage may also be chosen without restrictions. In most cases it would be mounted on the same panel with the other pressure gages, pyrometers, etc., regularly used for safeguarding the engine.

As long as the pressure p_1 (Fig. 1) is lower than the minimum with which it is safe to operate the engine the spring pushes the diaphragm button against a stop, so that the ball valve is held wide open while oil flows without appreciable resistance through the opening d_3 in the diaphragm and is discharged through the friction tube d_1 without causing a noticeable pressure rise in the gage line *b*. With increasing speed of the engine and force-feed lubricating oil pump, the oil pressure increases up to the point where it not only forces additional quantities of oil through d_3 but also builds up a sufficient pressure head against the diaphragm to make it compress the spring and to allow the ball valve to come closer to its seat. Further increases in the pressure p_1 tend to close the valve still further, but cannot do so entirely because then the pressure p_2 would fall so low that the diaphragm would be released again and would admit sufficient additional oil to deflect the diaphragm. Hence at values of the pressure p_1 which are higher than a predetermined lower limit—generally the lowest pressure of the lubricating oil with which it is safe to operate the engine—the ball valve is kept floating at a slight distance off its seat, while the diaphragm floats between the pressures $p_2 - p_1$ corresponding to the head of oil necessary to cause flow through the calibrated hole d_1.

Movements of a few thousandths of an inch by the diaphragm are sufficient to make relatively large differences in the valve opening, whereas the spring would have to be extended

or compressed by much larger amounts in order to make an appreciable difference in the force which it exerts. For all practical purposes, therefore, the elastic force exerted by the spring and diaphragm is constant within the operating range of the instrument. The only other forces available for balancing this constant spring force are the pressures p_2, less p_3, the latter acting on the under side of the diaphragm. The difference of the pressure above and below the diaphragm multiplied by the effective area of the latter keep it in equilibrium against the spring and the small elastic force of the diaphragm itself. Should there be any tendency to change the value of $p_2 - p_3 = p_5$, the diaphragm would immediately move slightly in such a direction as to correct the valve opening and to restore equilibrium.

With a constant pressure head maintained on opposite sides of the diaphragm, it is possible for only one definite quantity of oil in terms of pints per minute, say, to flow through the orifice d_3. This fixed quantity, as already described, escapes through the friction tube d_4.

A liquid of zero viscosity would theoretically escape through d_4 without building up any pressure under the diaphragm and would cause the pressure gage to register 0. At the same time the action of the diaphragm would be as described above, with the pressure $p_3 = 0$ (14.7 lbs. per sq. in. Abs.). An actual liquid flowing through d_4 will, of course, build up a pressure p_3, while p_2 will be raised correspondingly and the difference $p_1 = p_2 - p_3$ will be maintained without change. The gage connected to b shows the friction head proportional to the viscosity of the oil, and as quantity variations have been ruled out in the manner previously described, the viscosity effect is the only one to which the gage can respond.

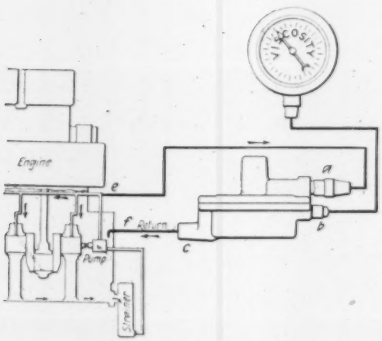


Fig. 2

The operation of the instrument is thus seen to correspond more nearly to the law of Poiseuille, on which the definition of viscosity is based, than does the Saybolt viscosimeter. The later measures the time required for a standard quantity of oil to flow through a standard orifice by gravity, so that the oil falls through under a variable head and the measured time required for the process is at best an arbitrary indication of the quantity really sought after.

Viscosity impaired by excessively high oil temperature is just as certain to ruin bearings as reductions in viscosity arising from other causes, such, for instance, as dilution with fuel oil. However, it is a simple matter to insert a thermometer in the oil line close to the instrument and to determine the viscosity as a function of temperature. Should the viscosity increase beyond permissible limits for any reason, the instrument will also show it.

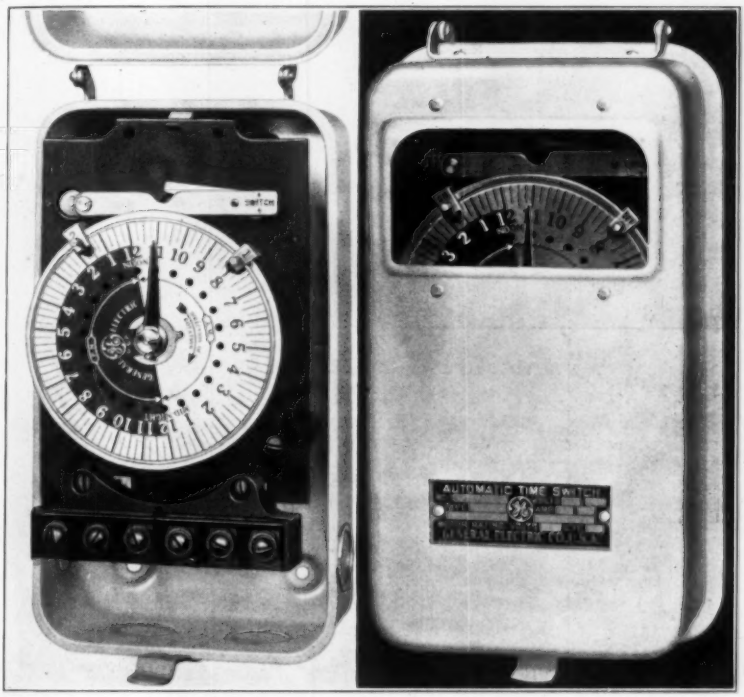
Operators of engine plants and automotive equipment should find the instrument a valuable safeguard both of the monetary value represented by the lubricating oil and of the value in the engine. Its use should quickly lead to a clarification of the question regarding the minimum value of viscosity with which it is safe to operate Diesel engines. The fact that no such value is now definitely known should not detract from the value of the instrument. Operators who read outlet water temperatures on cylinder heads do not know definitely how high the temperature may go before cracking will occur, but they watch the thermometer pretty closely just the same. The same is likely to be true of the automatic viscosimeter, whose readings—constantly available from a glance at dial—will quickly enable operators to correlate such factors as bearing wear and the condition of their surfaces with the true viscosity of the oils they are using.

The Ellison Draft Gage Company of Chicago announce the appointment of the Hauer Power Equipment Company, Union Trust Building, Cincinnati, as exclusive representative in the Cincinnati and southwestern Ohio territory.

New Time Switch

TO duplicate the possibilities of a new type of time switch, a man would need an almanac, a knowledge of latitude and longitude, a precise watch, a degree of punctuality far above the average, and the ability to be awake and alert at all hours.

The switch, a product of the General Electric Company, will turn lights on and off at dusk and at dawn, or at any predetermined time before or after sunrise and sunset; and will make due allowances for geographical latitude and for the season of the year. It can be made to take holidays, omitting its operations on any desired days of the week. It can perform such operations as starting motors in the morning, starting and stopping them throughout the day according to schedule and shutting them down at the end of the day. It will care for industrial heating problems, since by its use apparatus may be turned on early in the morning so as to be ready for the workmen when they arrive.



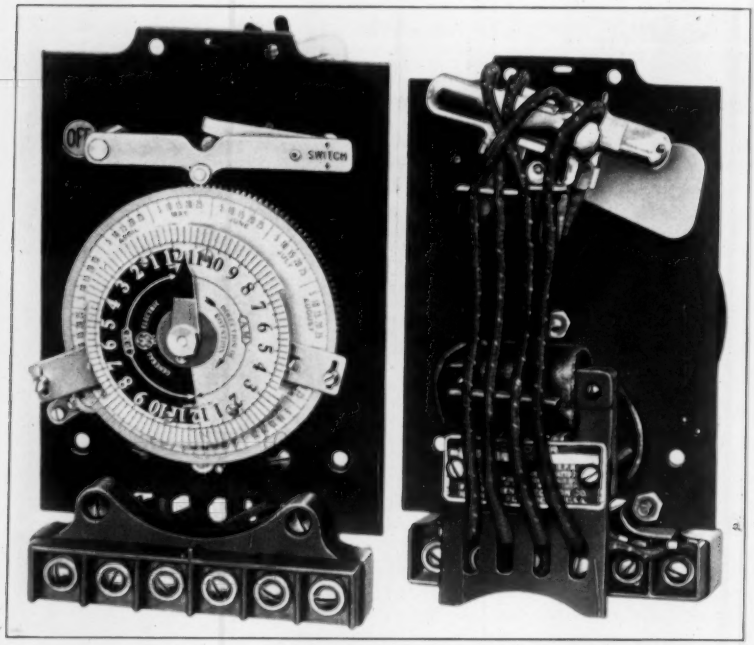
Cover Open Cover Closed

Type T-13 Time Switch.

The new switch can do two things at once. In an apartment house, for instance, it can turn on the hall and fire lights at dusk, turn off the hall lights at midnight, and keep the fire lights on until dawn. In the home the switch replaces the "alarm clock" control that more than one ingenious jack-of-all-trades has contrived to turn on this or that before it is time to arise.

Not all the above duties can be performed by the one switch, but various designs are available for such different tasks.

Three features of the new time switch, designated as GE Type T-13, are the use of the G. E. Telechron motor, as used in electric clocks, for timing the device; the employment of mercury-to-mercury Kon-nec-tor switches; and the availability of astronomic dials, corrected for latitude. It is designed for alternating-current circuits of 115 volts and 30 amperes or 230 volts and 15 amperes current-carrying capacity. It is available in single or double-pole, both single- or double-throw, and with either a plain or an astronomic dial. Apartment-house lighting is cared for by still another model, the two-circuit form.



Front View Rear View
Type T-B Time Switch, equipped with astronomic dial, without case.

Two adjustable riders ("on" and "off") give two operations every 24 hours. Except in the cases of the astronomic and two-circuit types, additional riders may be installed to give practically any number of operations daily; and the addition of an omitting device permits one or more days to be skipped if desired.

The housing is such that the time switch can be used for either indoor ar outdoor service. The case measures $10\frac{3}{16}$ inches in height, $5\frac{3}{8}$ inches in width, and 5 inches in depth. The instrument weighs $6\frac{1}{2}$ pounds.

New Wide Field Magnifier

(Bausch & Lomb Optical Co.)

THIS instrument has been developed in answer to a demand for a magnifier covering a much wider field than other similar instruments heretofore available. The field covered is one and one-half inches in diameter at a magnification of three times.

Two stands have been designed for use with the Wide Field Magnifier, the horseshoe base and the parallel arm stand, the latter being shown in the accompanying illustration.

The new instrument is particularly well adapted for many purposes. Photographers, photo-engravers, artists and bench workers in the optical, jewelry and watchmaking trades and in many other lines of activity will find the extremely wide field offers many advantages.

An important feature is that, unlike most magnifiers, the eye does not need to be brought close to the lens in order to see the full field.

New Photo-Electric Lighting Control Relay

(Westinghouse Elec. & Mfg. Co.)

THE operation of this lighting control relay is effected by variations in the intensity of light falling on a photo-electric tube. These variations produce proportional changes in the amount of current passing through the tube; and this changing current, amplified in a specially designed amplifier tube, energizes a primary relay controlling an auxiliary contactor, which, in turn, operates the main contactor controlling the lighting installation.

On the upper side of a micarta panel in a cast-aluminum box, with a glass hood to admit the light, are mounted the photo-electric tube, the amplifier tube, and the primary relay; mounted under the panel are fixed condensers, a transformer, the auxiliary contactor, and potentiometers for adjusting the device for operation at different intensities. Two dials, mounted on a panel on the side of the box, are used for regulating the potentiometers, one controlling the intensity at which the device turns on lights, and the other the intensity at which it turns them off. The foot-candle range of these dials is varied by a three-position plug switch located between them.

Some of the many applications for this device are found in providing automatic control for lights in office buildings; show windows; signs; schools; and in floodlighting, street lighting, airport lighting, and navigation lighting installations.

With a photo-electric lighting control relay installed in an office or a factory, variations in natural light can never interfere with good working illumination on any day of the year, since control of the lights is entirely independent of individuals' judgment, which is usually inaccurate. The use of this relay also effects savings in power; it has been found in several installations that automatic control of factory interior lighting has saved approximately one half of the power needed without such control.

Automatic control applied to illuminated signs and show windows effects a maximum of advertising value, since it turns on their lights whenever artificial lighting can increase their visibility, and turns them off when artificial illumination fails to enhance their attention-getting power. During early morning hours, usually from one to five o'clock, a time clock may be used to turn off the lights, a combination of the lighting control relay and a time clock giving complete automatic control of illumination.

Leaflet 20513 published by the Westinghouse Electric and Manufacturing Company describes the photo-electric lighting control relay, giving application, operation, construction, and installation details.

Above The new Photo-Electric Lighting Control Relay with Panel Removed Showing Adjusting Dials and Plug Switch.

At right The Photo-Electric Lighting Control Relay Installed in an office for Turning the Artificial Lights On and Off without Human Supervision.

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POTENTIOMETER PYROMETERS. A broadside describing potentiometer pyrometers used for heat-treated products. Leeds & Northrup Co., 4901 Stenton Avenue, Philadelphia, Pa.

GROUNDING NOTES. No. 6 Vol. 1 of this pamphlet contains an article entitled, "Why Ground Resistances Should Be Measured." Hubbard & Company, Pittsburgh, Pa.

SPECTROGRAPH. Two circulars entitled "Moll Infra-red Spectrograph" and "Spectra obtained with the new f/2 Spectrograph producing luminous spectra." P. J. Kipp & Zonen, Delft, Holland.

SHEET METAL TESTER. A leaflet describing Model-G2 Sheet Metal Tester. Detroit Testing Machine Co., 5137 Trumbull Avenue, Detroit, Mich.

NEPHELO- and ABSORPTIOMETER. A card describing and illustrating the Nephelo- and Absorptio-meter for monochromatic light. Kipp & Zonen, Delft, Holland.

AUTOMATIC REVERSAL. A folder entitled, "New Efficiency-New Economy for the Open-Hearth." Leeds & Northrup Company, 4901 Stenton Avenue, Philadelphia, Pa.

CONTACTOR. A circular describing a contactor for mill and crane controllers. Westinghouse Electric & Manufacturing Co., East Pittsburgh, Pa.

INSTRUMENTS. Bulletin No. 174, a bound booklet of 32 pages, covers the maker's complete line of controlling, recording and indicating instruments for temperature, pressure, humidity and flow. The Foxboro Company, Foxboro, Mass.

MOISTURE METER. Bulletin 998 illustrates and describes a moisture meter which accurately and quickly determines the moisture content of wheat. C. J. Tagliabue Mfg. Co., Park & Nostrand Aves., Brooklyn, N. Y.

PRECISION BORERS. Catalogue No. 534 describes "SIP" boring machines, illustrates various accessories and shows typical jobs done with figures of the time saved and the accuracy obtained. The R. Y. Ferner Co., Investment Bldg., Washington, D. C.

RADIO TESTERS. A letterhead leaflet describing and illustrating visible counter tube and portable tube checkers. Also senior and junior test oscillators are described. Burton-Rogers Company, 755 Boylston Street, Boston, Mass.

THE HAYS RECORDER. "Sample No. 1" of a house organ "aspirated at intervals" by The Hays Corporation, Michigan City, Ind.

MAIHAK INDICATOR. Bulletin 3265 describes Maihak indicator for greater efficiency in gas engine operation. Bacharach Industrial Instrument Co., 7000 Bennett St., Pittsburgh, Pa.

VACUUM THERMOCOUPLES. A leaflet describing vacuum thermocouples for measuring weak alternating currents. P. J. Kipp & Zonen, Delft, Holland.

MICROSCOPES. A 12-page booklet entitled, "The Microscope must be worthy of the Physician," a folder on the GSE binocular microscope; also a folder on B & L inclined binocular body tube. Bausch & Lomb Optical Company, Rochester, N. Y.

OPEN HEARTH FURNACE CONTROL. A reprint from May 7, 1931 issue of *Steel* entitled "Controls Open Hearth Reversal by Temperature Difference" by H. R. Simonds. Leeds & Northrup Co., 4901 Stenton Avenue, Philadelphia, Pa.

OSCILLOGRAPH, DEMAND METER. Circular L 20521 describing Type PA Automatic Oscillograph and Circular L 20498 describing Type RB Recording Demand Watthour Meter. Westinghouse Electric & Manufacturing Company, East Pittsburgh, Pa.

TECHNICAL INSTRUMENT BULLETIN. The June, 1931 issue of this publication features an article entitled, "Two Arrangements for Illumination with Reflected and Oblique Light" by F. Hauser, Ph.D. Emil Busch Optical Co., Ltd., 37 Hatton Garden, London, E.C.1, England.

SPECTRUM ANALYSIS. Bulletin No. 3 contains the following articles: "Mineralogical Applications;" "Chemical and Metallurgical Applications;" Biological and Sundry Applications," etc. Adam Hilger, Ltd., 24 Rochester Pl. Camden Rd., London, N.W.1, England.

SERVICING AIRCRAFT INSTRUMENTS. Reprint of an article by George Tate, Jr. This article was prepared in view of the fact that a recent Department of Commerce ruling requires all air transport operators engaged in interstate passenger carrying maintain adequate personnel and equipment for the checking and maintenance of flying instruments. Pioneer Instrument Company, 754 Lexington Avenue, Brooklyn, N. Y.

WATCHES. A circular describing and illustrating stop watches and split-second timers. The Sterling Stop-Watch Co., Inc., 15 East 26th Street, New York, N. Y.

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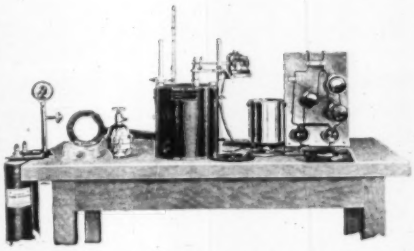

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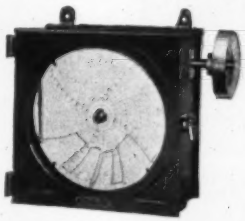

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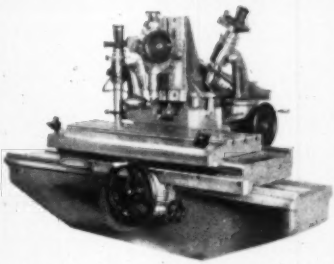

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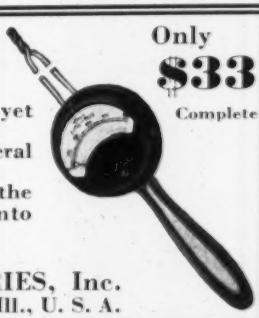

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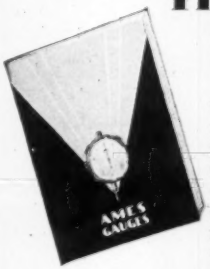

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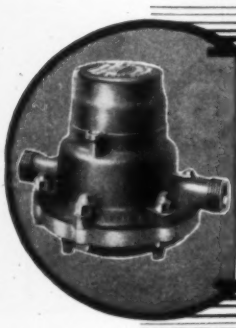

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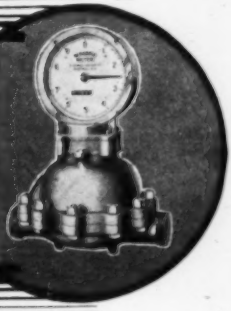

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THE DETERMINATION OF LOW PERMEABILITY. FRANK P. FAHY. INSTRUMENTS, Vol. 4, No. 9, September, 1931, pages 475-479, 3 figs.

After summarizing the classical methods of measuring permeability, the author proposes a new one applicable to materials of magnetic characteristics scarcely greater than unity, and describes the requisite apparatus.

MEASUREMENT OF AIR FLOW. E. OWER. INSTRUMENTS, Vol. 4, No. 9, September, 1931, pages 480-488, 5 figs.

Chap. VIII. Miscellaneous methods of flow measurement depending on pressure observations.

SPEED AND ACCELERATION MEASUREMENT. M. F. BÉHAR. INSTRUMENTS, Vol. 4, No. 9, September, 1931, pages 489-503, 14 figs.

Continuation of Chap. XV of Handbook of Industrial Instruments. This instalment covers:

Section 15. Electric Tachometers
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